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The North Kaibab Pandora Moth Outbreak, 1978–1984

J. M. Schmid and D. D. Bennett

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Small egg mass attached to ponderosa pine needle. Note head capsule appearing as dark spot on each egg.

Recently hatched first instar larvae and unhatched eggs.

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Abstract

A pandora moth outbreak in Arizona was studied from 1979 to 1985 to determine the moth's life cycle, densities and distribution of life stages, larval and adult behavior, effects of the defoliation, sampling procedures, importance of biotic mortality factors, and the effectiveness of insecticides. This report summarizes the available published and unpublished information on the outbreak.

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[1]*Headquarters is in Fort Collins, in cooperation with Colorado State University.*

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Introduction

On August 1, 1978, a forester's son, accompanying his father during his field work, observed and collected several large moths in ponderosa pine (*Pinus ponderosa* Lawson) stands west of Jacob Lake, Ariz. (Sanders 1981). These specimens were later identified as pandora moths (PM), *Coloradia pandora* Blake. The moths, probably mostly spent males, were among the progenitors of larvae that caused the significant defoliation in 1979 and first alerted forest personnel to the outbreak. At the time, neither observer realized he was witnessing the beginning of the most extensive pandora moth outbreak recorded in Arizona and, perhaps, in the western U.S. This outbreak exhibited the classical textbook changes—an explosive population increase from an endemic level, followed by an equally rapid population decrease—all within four generations.

Although notable pandora moth outbreaks had occurred in California-Oregon (Patterson 1929) and Colorado (Wygant 1941), only limited biological information was gleaned from them. Key elements of the life history of this Kaibab population differed from previously reported information. Because the defoliation concerned forest managers, the North Kaibab outbreak was used to gather important new information and test hypotheses.

To simplify the presentation of information and reduce extensive descriptive phrases, the different generations and their respective defoliation areas are hereafter generally referred to as shown below and in figure 1.

Gen. I	August 1978–August 1980	Caused 1979 defoliation in Defoliation Area I (DA I)
Gen. II	August 1980–August 1982	Caused 1981 defoliation in Defoliation Area II (DA II)
Gen. III	August 1982–August 1984	Caused 1983 defoliation in Defoliation Area III (DA III)
Gen. IV	August 1984–August 1986	Caused 1985 defoliation

The reader should not rigidly adhere to the above time periods, because, as will be discussed later, some exceptions do exist. However, for practical purposes, the generations are best described as stated above.

Extent of the Outbreak

Estimates of visibly defoliated acres provide one measure of the extent of the outbreak. Pine stands on 5,120 acres (2,072 ha) (fig. 1) were moderately (51–75%) or severely (76–100%) defoliated in 1979 (USDA 1980), while light (26–50%) defoliation was noted on several

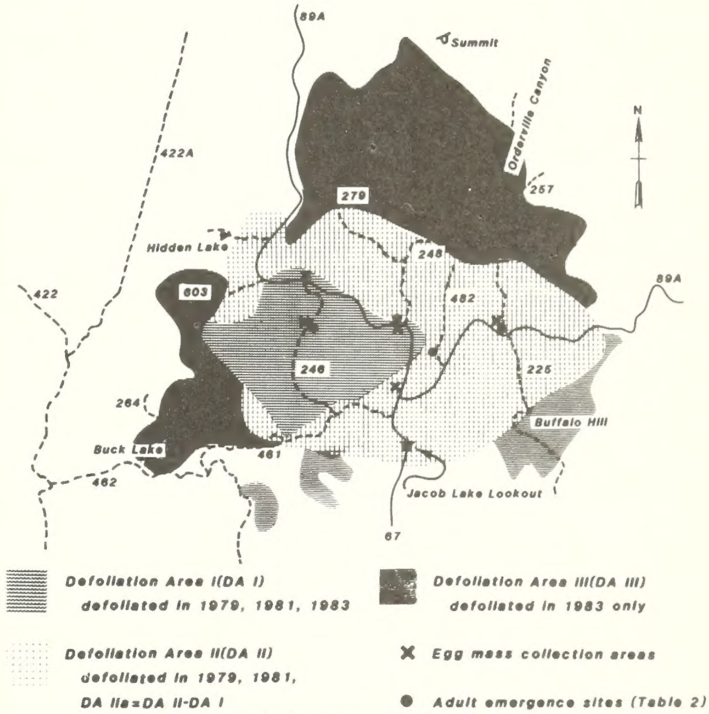

Figure 1.—Defoliation areas during the outbreak.

thousand additional acres. In 1981, approximately 18,700 acres (7,568 ha) were moderately or severely defoliated (USDA 1982); this area included the second defoliation of DA I. The 1983 area of defoliation covered 28,525 acres (11,544 ha), including most of DA II, but only 3,850 acres (1,558 ha) were severely defoliated. In 1985, no defoliation was observed during aerial detection surveys, although a few scattered individual trees in the peripheral area of DA III were observed from the ground.

During this outbreak, the combined areas of moderate and severe defoliation, as well as the estimated total acreage of defoliation, changed dramatically from one defoliation period to the next. For the different time periods, the ratios were as follows.

Defoliation periods	Defoliated area: Combined moderate and severe	Defoliated area: Total estimated
1977:1979	1:>5,000	1:>8,000
1979:1981	1:3.7	1:2.2
1981:1983	1:.82	1:1.5
1983:1985	1:0	1:0

In both cases, although the area of observable defoliation increased with each generation, the rate of increase declined.

The 1977:1979 ratio is the most interesting ratio, because it reflects the critical change from the endemic population to the outbreak level. However, the population may not have really increased to that level in one generation; rather, it may have increased to outbreak status in the unobserved August 1976–August 1978 generation preceding our Gen. I. This generation could have caused unnoticed defoliation over several hundred acres in 1977 and, subsequently, increased to the observable levels in Gen. I. Because the 1977 aerial survey of the North Kaibab Ranger District was conducted in early September, it may have failed to detect light to moderate defoliation in May because of July refoliation. Further, support of this "missed defoliation-generation" hypothesis came during the aerial detection surveys, flown August 1 and 2, 1985, when Bennett noted the difficulty of seeing pandora moth-caused defoliation at a new known outbreak location near Cape Royale, Grand Canyon National Park.

The extent of the outbreak is not fully characterized by the acres of defoliation. Adults were observed in Fredonia, Ariz., and Kanab, Utah—30 to 40 miles (48 to 64 km) northwest of Jacob Lake; Panguitch, Utah—110 miles (176 km) north of Jacob Lake; Marble Canyon and Lee's Ferry, Ariz.—40 miles (64 km) east of Jacob Lake; North Rim of Grand Canyon National Park—40 miles (64 km) south of Jacob Lake; Tusayan, Ariz.—55 miles (88 km) south of Jacob Lake; Cameron, Ariz.—114 miles (182 km) southeast of Jacob Lake; and Flagstaff, Ariz.—165 miles (264 km) mostly south of Jacob Lake (Tusayan, Cameron, and Flagstaff are south of the Grand Canyon). All but the North Rim location were disjunct from the original host type by at least 10 miles (16 km) of nonhost vegetation. Moths at all but the North Rim site were believed to have entirely dispersed to these localities on vehicles. While the only new infestation arose at the Grand Canyon site, the presence of moths at these other locations indicates the distances forest insects can spread when high population levels exist in a high-use recreation area.

Life Cycle

The life cycle lasted 2 years for essentially all of the pandora moth (PM) population. Moths began emerging in late July of even-numbered years. Peak numbers emerged around mid-August, and by the end of August over 99% of the moths had emerged. Less than 1% of the moths emerged in September or emerged the following year, which created a 3-year cycle. Moths were observed in October, but these were tattered males which probably had emerged in late September.

Egg masses (EMs) were laid shortly after adult emergence; thus, egg deposition lasted from late July through early September. Because the egg stage lasted at least 40 days and longer, unhatched masses found in October and November had been deposited in August or September.

Larval emergence began in late September and lasted into November, with most larvae emerging in October. Most of the small number of unhatched egg masses noted in November were probably infertile or parasitized. First and second instars predominated in November of even-numbered years, with the second instar becoming the predominant stage during December and January. By mid-February, third instars could be found, particularly if above average temperatures occurred. As larvae more actively fed in April and May, they passed through the third and fourth instars until the fifth instar predominated in June. Fifth instars left the tree in late June and entered the ground to pupate. After entering the litter or soil, the larvae transformed to pupae through a prepupal stage during which they contracted in length and thickened in width.

Pupae predominated for the next 12 to 13 months, or roughly from July of the odd-numbered year until July to August of the following even-numbered year. Pupae were found after most moths emerged, but nearly all of these remaining pupae did not produce adults. A very small percentage emerged 1 year later, becoming the 3-year-cycle moths.

Oviposition Sites

Female moths oviposited on just about every conceivable object in the forest. Ponderosa pine was the primary site, with the egg masses predominately deposited on the foliage. The lower boles of trees 12 inches (30 cm) and greater in diameter (d.b.h.), particularly trees near light poles, received high EM densities (fig. 2). Pinyon [*Pinus edulis* (Engelm.)] and Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) also were deposition sites in the natural forest. Egg masses stick well to needles and bark and were seldom dislodged during sampling, unless the needles or bark were broken off. Females did not confine their oviposition strictly to trees but also deposited eggs on cabins, rocks, and vehicles. Egg masses were particularly abundant on light poles, to which adults were attracted at night (fig. 3).

Immature Stages—Densities and Characteristics

Egg Numbers

Female moths were collected as they emerged and later dissected to determine the average number of eggs per female; the average number was 145, (range 108–188). Females with less than 100 eggs may have already deposited a cluster before examination.

Eggs were laid individually, and in groups of 2 to 38, but more than 20 and less than 3 were rare. Individual eggs adjacent to egg masses were probably either disconnected from the larger mass or resulted from disrupted deposition by a disturbed female.

The mean number of eggs per mass was 11 in 1980, but the modal number was 8 (Schmid et al. 1982b). In 1982, eggs per mass ranged from 3 to 30 (N = 105). The mean number per mass ranged from 11 to 15 in five different stands, while the modal number ranged from 9 to 12.

Location	Eggs per mass	Modal number per mass
"A" area	12.1 ± 4.6	12
Telephone plot	15.1 ± 5.0	11
"I" test		
Aug. 1982	11.1 ± 4.1	9–10
Oct. 1982	12.7 ± 5.3	12
Jacob Lake	12.0 ± 5.5	9
Burro Burn	12.8 ± 5.4	12

Eggs per mass were not significantly different between Gen. I and Gen. II (1980 and 1982). Eggs per mass were not studied in 1984, but the number per mass appeared the same as in previous generations.

Egg Mass Densities

Egg mass densities (EMDs) varied significantly among areas, depending on their defoliation status. In 1980, based on whole branch samples from trees ⩾12 inches (⩾30 cm) d.b.h., EMDs were not significantly different ($p = 0.06$) between severely and lightly defoliated stands (Schmid et al. 1982b). However, the mean EMDs for each crown level in the severely defoliated area were consistently greater than the respective densities in the lightly defoliated area, which suggests the differences might have been significant if additional samples had been taken. On trees 7 to 10 inches (18 to 25 cm) d.b.h., EMDs on whole branches were significantly greater in the severely defoliated area. In 1982, an egg mass evaluation, using one branch tip from each tree in forty-one, 5-tree clusters, indicated EMDs were greater in areas defoliated by the previous generation (Gen. II) than in areas severely defoliated by the two previous generations (Gen. I and Gen. II) or in essentially undefoliated areas (Schmid et al. 1983). Even though the population collapsed in 1983 during Gen. III, EMDs in 1984 were still significantly greatest in the area sustaining moderate to severe defoliation the previous year (1983) by Gen. III and significantly lower in areas previously defoliated two or three times or essentially undefoliated (table 1).

EMDs, throughout the outbreak, thus followed the pattern of defoliation—being significantly greater in areas moderately to severely defoliated by the previous generation and significantly lower in areas sustaining the same levels of defoliation by two or more previous generations or in undefoliated areas. The greater EMDs were present for only one generation in any specific area and, thereafter, declined to levels greater than the endemic level (i.e., ca. 0), but never as great as the previous high. These densities probably occurred because adult densities were greater there, and females oviposited more eggs in the area where they developed (Schmid et al. 1983). Females with a full complement of eggs may be too heavy to fly and, therefore, must deposit the majority of their eggs before dispersing.

EMDs were significantly different among trees in areas sustaining severe defoliation by two successive generations but were not different in the same size trees from areas sustaining other levels of defoliation (Schmid et al. 1983). The differences in the heavily defoliated area probably resulted from greater foliage production by some trees that were then more suitable as oviposition sites. During Gen. I and Gen. II, defoliation appeared uniform in most areas and did not differ significantly among trees. If stands were severely defoliated, then nearly all trees were severely defoliated. If stands sustained only light defoliation, then nearly all trees had light defoliation. However, during Gen. III, differential tree defoliation appeared as virus-caused larval mortality affected the PM population at different times.

EMDs varied significantly by crown level, depending on tree size and sampling unit. On both lightly and severely defoliated 50- to 80-foot (15- to 24-m) trees, EMDs were significantly greater in the lower crown than

Table 1.—Egg mass densities[1] ($\bar{x} \pm SD$) per branch, per nine shoots, and per 100 cm of branch length from undefoliated areas and areas defoliated one, two, or three successive times.

Sample unit	Years of defoliation[2]	Egg mass collection years		
		1980	1982	1984
Branch	0	7.5 ± 3.0 a	5.8 ± 5.1 a	0.4 ± 0.6 a
	1	10.2 ± 4.6 a	13.5 ± 10.6 b	1.5 ± 1.3 b
	2		7.0 ± 5.9 a	0.5 ± 0.8 a
	3			0.3 ± 0.6 a
Nine shoots	0		3.0 ± 3.0 a	0.4 ± 0.6 a
	1		7.5 ± 6.4 b	1.2 ± 1.1 b
	2		3.6 ± 3.5 a	0.4 ± 0.7 a
	3			0.2 ± 0.5 a
100 cm of branch	0		4.8 ± 4.3 a	0.4 ± 0.7 a
	1		11.4 ± 9.3 b	1.7 ± 1.4 b
	2		6.3 ± 5.6 a	0.6 ± 1.0 a
	3			0.4 ± 0.7 a

[1]*Means within the same collection year and sampling unit, followed by the same letter, are not significantly different.*

[2]*Defoliation occurred in 1979, 1981, and 1983.*

in the upper crown on a per branch and per foot of branch basis (Schmid et al. 1982a). Some of the difference on a per branch basis was attributable to branch size, the branches being considerably larger in the middle and lower crown. However, on the foot of branch basis, EMDs were greater in the lower crown.

On 25- to 50-foot (8- to 15-m) trees, EMDs were not significantly different among crown levels in either lightly or severely defoliated trees. EMDs per branch showed no trend in either defoliation class, but EMDs per foot decreased insignificantly from top to bottom in the lightly defoliated trees. These results differ from those of Buffam and Thompson (1964), who found significantly greater numbers in the upper crowns of 6- to 27-foot (2- to 8-m) trees. Because most of our trees were taller, the results are not wholly comparable. Further, their results indicated no significant differences between the upper and middle crowns. Thus, their middle and upper crowns may be comparable to our lower crowns so that crown level differences may not exist for 20- to 50-foot (6- to 15-m) trees.

EMDs on the foliage were not significantly different for the four cardinal directions within trees of the same size on specific locations (Schmid et al. 1983).

On the boles of large and small trees in a heavily defoliated area, EMDs were greatest within 1 foot (30 cm) aboveground. In lightly defoliated areas, EMDs were uniform throughout the first 20 feet (6 m) of large trees, but were greater in the first foot of smaller trees. The greatest EMDs were observed on the basal portion of light poles, because adults congregated on the poles during the evening hours (fig. 3).

Larval Instars

Head capsule width measurements indicated five instars were present during the larval stage. Widths for each instar ranged as follows.

Instar I	0.04–0.05 inches	(1.14–1.33 mm)
Instar II	0.06–0.08 inches	(1.56–1.98 mm)
Instar III	0.08–0.11 inches	(2.13–2.70 mm)
Instar IV	0.12–0.17 inches	(3.14–4.42 mm)
Instar V	0.18–0.23 inches	(4.65–5.90 mm)

Larval Densities

Based on branch tip samples, larval densities varied significantly between areas and among aspects within a tree but did not vary significantly among crown levels. Larval numbers were greater on the relatively level ridgetops than in adjacent ravines. These differences probably resulted from moth ovipositional behavior, which favored the environment of the homogeneous stands on the ridges.

Larval densities changed significantly among aspects as the larval period progressed. Just after egg hatch, first instar larvae were equally dense on all aspects. By late October, larval densities became significantly greater on the south sides and lower on the north sides. Larvae probably immigrated to the south to benefit from more favorable temperatures during winter. Larvae remained mostly on the south sides until the following April, when more larvae moved to northerly aspects. By mid-May, larval counts were greater on the north sides.

Larval densities in late October 1982 averaged 22 to 34 per 2-foot (0.6-m) branch tip in 10 stands severely defoliated in 1981, with counts of over 75 larvae per tip in some samples. In mid-May, larval counts averaged 3 to 4 per branch tip, with rare counts of 20 to 30 per branch tip. The larvae were much larger in size at this time, but overwintering mortality greatly reduced their numbers.

Pupal Dimensions

Female pupae averaged 1.3 inches (3.2 cm) long, with a range of 0.9 to 1.4 inches (2.2 to 3.6 cm) (n = 72). Male pupae averaged 1.3 inches (3.2 cm), with a range of 1.1 to 1.3 inches (2.7 to 3.4 cm) (n = 90).

The weight of female pupae averaged 0.09 ounces (2.7 grams), with a range of 0.04 to 0.13 ounces (1.2 grams to 3.7 grams). Male pupae averaged 0.07 ounces (2.1 grams), with a range of 0.04 to 0.13 ounces (1.0 to 3.6 grams).

Pupal Densities

Pupal densities varied with topography, canopy cover, litter depth, and proximity to trees. Densities were greatest on flat areas and decreased slightly when slope increased up to 10%; when slope was >10%, densities no longer decreased with increasing slope. Numbers of pupae were greater under an open canopy than a closed canopy (Miller and Wagner 1984). Densities also were greatest when litter depth was <1 inch (1 to 2 cm) but relatively equal throughout lesser and greater litter depths (Miller and Wagner 1984). Densities from plots ≥5 feet (1.5 m) from the bases of canopy trees were greater than from plots within 2 feet (0.2 m) of the tree bases (Schmid, unpublished); but, within 10 feet (3 m) of the tree bases, pupal densities were relatively equal. Densities also were equal on the four cardinal directions (Schmid et al. 1982b).

The pupal densities reflected the relative importance of site factors and larval behavior. Densities were greatest on the flat ridgetop areas with no or little slope, because this is where larval densities were greatest. As larvae descended from the crowns and departed tree bases, they apparently searched for pupation sites with 0.4 to 1.2 inches (1 to 3 cm) of litter. Beneath canopy trees, such areas usually were below the dripline of the crown where litter accumulation would be least and the canopy cover partially open. In pole and sawtimber sized stands, such areas were 10 feet (3 m) or more from the base of the tree, which accounts for the greater pupal numbers away from the tree bases than adjacent to them. However, litter depth may not have been the most important factor determining pupal densities. In 1980, Gen.

I pupae were found in densities of 20 or more per square foot (215/m^2) adjacent to the bases of sawtimber trees, where litter depth was 3 to 4 inches (7.6 to 10 cm). Frequently, larvae congregated in areas where litter depth was excessive or essentially absent, which suggests that larvae may leave some type of scent trail. Subsequently, pupating larvae might follow this trail and pupate in the same location. This could account for the high numbers of pupae found under tufts of grass when other adjacent tufts yielded no pupae.

During Gen. I and Gen. II, mean densities and the range of densities were similar. Gen. I pupal densities from three locations had mean densities of 3.0 per square foot (32/m^2) and ranged from 0 to 32 per square foot (0 to 344/m^2). Mean Gen. II densities were 1.2 near the bases of trees and 2 in areas more than 10 feet (3m) from trees; range equaled 0 to 30 per square foot (0 to 323/m^2). Gen. III densities were not studied.

Moth—Behavior and Numbers

Emergence and Sex Ratio

In 1982, moths began emerging the last week of July (Schmid 1984). A few adults were observed around lights at Jacob Lake and some were caught in cages. The number of moths emerging daily continued at a low level until August 4, when the number increased substantially (fig. 4). Numbers generally increased thereafter, and maximum numbers of adults emerged during August 10–15. After mid-August, numbers decreased until August 30, when daily emergence averaged 1 to 2 adults per 400 square feet (37 m^2) per day. Even at this low rate, over 100 moths per acre were emerging. Moths were observed on September 22, indicating a few moths emerged well after most of the population (99%) had emerged.

Moths at the 7,600-foot (2,316-m) elevation emerged about 10 days before the first adults appeared at 7,800 feet (2,377 m). The combination of higher elevation and north aspect probably caused slower development at the higher elevation.

Moths emerged after late summer rains began on the North Kaibab. Rains apparently softened the dry, cementlike soil surface, allowing adults to emerge with less difficulty and, consequently, increased population survival.

Both sexes emerged during the first 10 days of the emergence period in 1982, but males outnumbered females by a 3–4:1 margin. As the emergence period progressed, the sex ratio shifted so it was essentially 1:1 during peak emergence and then 1:1.5 during the last 10 days of August.

Population Numbers

Based on emergence in 250 screen cages, each covering 1 or 2 square feet (0.09 or 0.18 m^2), the number of moths emerging per square foot of ground surface ranged from 0 to 13 (table 2). Mean densities on ridgetops and midslopes were generally higher than in ravines, but a significant difference between ridgetop and ravine was not universally found. The low densities in ravine bottoms were expected, because previous observations indicated defoliation was less on trees there. The reason for this elevation variability is not known; but, because females are generally active only at night, and the ravine bottoms are noticeably cooler, females may be more active in the warmer thermoclines on the ridgetops and less active in the ravine bottoms. This explanation also may account for the broader pattern of infestation, wherein successive ridges had greater densities of larvae and greater defoliation than did broad, lower elevation areas between them (fig. 5).

The emergence pattern and trap catches of emerging moths reflect only a tiny proportion of the immense number emerging during an outbreak. If one moth emerged from every square foot of ground, then over 43,000 would emerge from each acre (109,220/ha). If this rate of emergence is assumed for the 19,000 acres (7,480 ha) moderately to severely defoliated by Gen. II larvae,

Table 2.—Number of emerging pandora moth adults per square foot of ground surface in 1982 (Schmid 1984).[1]

Site	FS Road 246 plot	U.S. Highway 89A plot	FS Road 482 plot	FS Road 257 plot
		$\bar{x}$ ± S.D.		
Ridgetop	0.4 + 0.8 a	0.8 + 1.2 a	2.4 + 3.2 a	1.7 + 2.4
Midslope	0.6 + 1.1 a	0.8 + 1.1 a	0.4 + 0.8 ab	
Ravine bottom	0.1 + 0.2 a	0.2 + 0.4 a	0.2 + 0.4 b	
		Range		
Ridgetop	0–3.0	0–4.0	0–12.5	0–13
Midslope	0–3.5	0–4.5	0– 2.5	
Ravine bottoms	0–0.5	0–1.5	0– 1.5	

[1]*Within columns, means followed by the same letter are not significantly different,* $\alpha = 0.05$.

then over 800,000,000 moths would have flown in 1982. Considering the numbers observed around the lights at Jacob Lake, around the bases of trees and flying above the tree crowns at twilight, the multimillion figure seems valid.

Behavior

Moths crawled upward through the soil and litter from their pupal site, so the first evidence of their emergence was litter movement. After emerging, they crawled over the litter surface until they encountered any upward-oriented object, including tree boles, dead limbs, grass stems, *Solidago* sp., *Lupinus* sp., cones, and stumps. Most herbaceous plants failed to support an adult; when the stems broke or bent, sending the moth to the ground, it resumed crawling and either repeated this process with other herbaceous stems or eventually encountered a supportive object. Ninety-nine percent of the adults settled on ponderosa pine boles of all sizes.

Most moths settled on the tree boles a few inches to 6 feet (1.8 m) aboveground, with maximum ascension being influenced by tree size and, perhaps, the distance they crawled over the ground surface before reaching the tree. On seedlings and saplings, moths climbed to various heights and frequently climbed to the tip of the leader. On larger trees, moths settled various distances aboveground, ranging from a few inches (cm) to over 18 feet (5.5 m). Some moths that crawled for more than 30 feet (9 m) before encountering a tree settled within 3 feet (1 m) of the ground, and others that crawled lesser horizontal distances settled higher on the bole.

Moths seemed able to discern large trees when they were within 6 feet of them but seemed to encounter seedlings and saplings by chance. Adults frequently crawled past seedlings and saplings that could have provided suitable resting places and continued crawling until encountering another object. Large trees were not bypassed when the moth was within 6 feet (1.8 m) of them, but were when they were more distant.

Moths usually settled in a shaded spot on the tree where they could hang without their abdomen touching any surface and expand their wings. The wings are not fully formed when they emerge, but begin to expand once the moths settle into position; usually with a lateral rocking motion, during which the antennae are folded close to their ventrolateral surface just above the legs. The wings were expanded within 15 minutes. At first, the leading edge of the unexpanded wings were oriented laterally from the body. As they expanded, the leading edges came together over the dorsal surface of the abdomen and projected outward from the body. The wings remained in this position for another 30 to 45 minutes. Then the leading edges were brought to the lateral sides of the abdomen, and the trailing edges formed a triangular tent over the abdomen.

Moths usually remained in the same positions on the boles for the remaining daylight hours unless disturbed or unless their location became exposed to direct sunlight. In such cases, the disturbed moths frequently moved higher on the tree. On sunny days, adults emerging in the morning were usually found on the north and west sides of the trees. Moths emerging in the afternoon were found on the north and east sides of the trees. On cloudy days, more adults were seen on southern exposures.

During the first days of the emergence period, little flight and mating activity was observed. Few females mated during the wing expansion period, and no egg masses were observed on tree boles. As the emergence period progressed, more moths were present, and hundreds of males were observed flying during the daylight hours. Males frequently hovered 3 to 6 inches (7.6 to 15.2 cm) away from the boles and flew vertically or laterally around the circumference at this distance, apparently in search of females. Newly emerged females frequently mated as soon as they began crawling up the tree or while at rest during wing expansion. As a result, egg masses became abundant in the first 6 feet (1.8 m) of the bole. This probably accounts for the greater density of egg masses in the first 1 foot (0.3 m) of the bole as observed by Schmid et al. (1982b). Furthermore, the highly disproportionate sex ratio favoring males in the initial days of emergence decreases the possibility that females go unmated and apparently increases the chances of survival of the species.

Females generally were not observed flying during daylight hours. This observation, the tendency to avoid direct sunlight (fig. 6), and the tremendous nighttime activity around lights at Jacob Lake, indicates most adults, particularly females, are crepuscular and nocturnal. Males nearing death were the moths most active during daylight hours. Such males usually have lost most of their gray-black coloration and have frayed wings. The presence of discolored, tattered, fluttering but flightless males near the bases of trees indicated these males were spent, probably near death, and seeking to mate one last time. Contrary to Tuskes' (1984) hypothesis of a behavioral change associated with outbreaks, diurnally flying males of this outbreak probably were behaving the same as during endemic population levels, but their numbers made them more evident, while endemic populations are too low in number to be noticeable.

Moth-People Interaction

Neither the larvae nor the adults caused any skin irritations, such as those cited by Tuskes (1984); however, their presence was a considerable nuisance. Attraction of the moths to night lights annoyed tourists, recreationists, and workers at the Jacob Lake Inn and adjacent campgrounds. During the evening hours of August 1982, thousands of moths congregated around the lights illuminating the gas station, tennis courts, and cabins. Moths landed on people, vehicles, and buildings, in addition to the ponderosa pines. They were abundant enough to cause cancellation of tennis games and the early closing of the gas station. Because one outside night light was near the Inn's main entrance, moths frequently crawled into the Inn and onto people and furniture.

Figure 2.—High egg mass densities were found on the basal section of large trees.

Figure 3.—Artificially high egg mass densities were found on the basal sections of light poles.

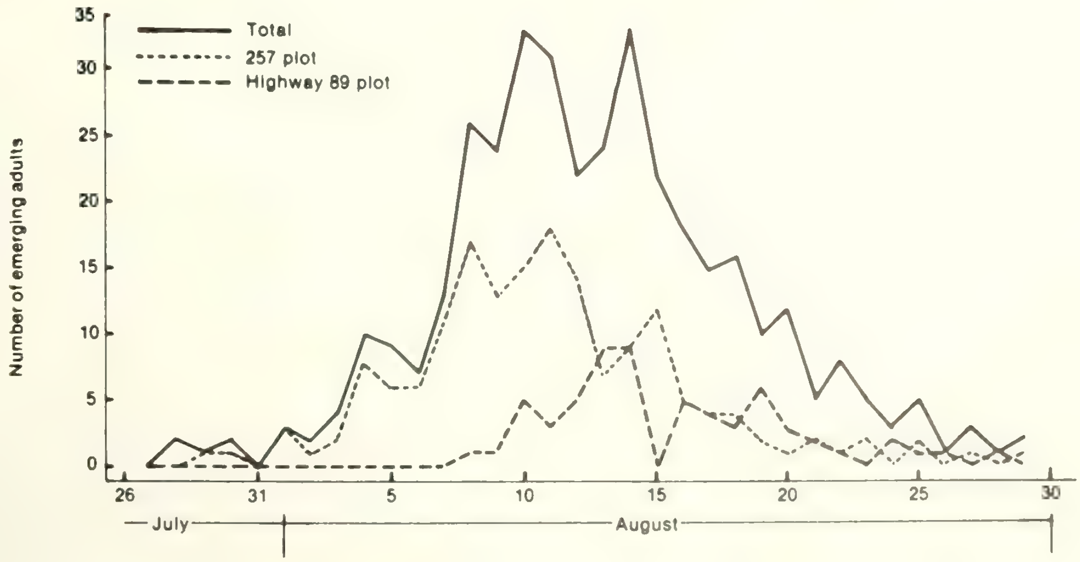

Figure 4.—Emergence period of pandora moths, 1982 (Schmid 1984).

Figure 5.—Color infrared photo of part of the defoliated area. Blue-green = defoliation; pink = nondefoliation.

Figure 7.—First instar larvae moving upward on bole. Note the single-file "follow the leader" behavior.

Figure 6.—Adults resting in shade on Jacob Lake Inn gas station. Note few are in the direct sunlight.

Figure 8.—Mature larvae moving toward the ground on the bole.

Figure 9.—Virus-infected larvae congregated around the leader of saplings.

Figure 10.—Mature larvae have consumed older needles but not new growth, which is just beginning.

Figure 11.—Severely defoliated trees were esthetically displeasing for only a few months because annual shoot growth began about the time defoliation ceased.

Figure 12.—Prescribed burning to kill PM pupae. Fires had to be burned at night (A) because conditions during the day were too extreme. Mortality was variable because the fire did not burn hotly throughout the area—note unburned areas in foreground (B).

Every morning following the massive nocturnal flight activity, especially during mid-August 1982, thousands of dead moths were swept up in the parking area immediately surrounding the main entrance light pole. Dead moths were so abundant that it was not possible to walk to the entrance without stepping on them—when the body was crushed, the noise was like popping popcorn. The accumulation of dead moths in a depression around one light pole combined with the abundant summer precipitation created a stench during August 1982.

Dispersal

Moth Dispersal

Moths disperse via their own ability and vehicular transportation. In natural dispersal, moths crawled from their pupal sites to nearby objects, generally trees, where they remained motionless while expanding their wings. Once the wings were fully developed, moths generally flew among the crowns the following evening, although females may have first crawled into the crowns before their initial flight. After wing expansion, moths were not seen on the ground again until they were so battered they could no longer fly.

The distance individual moths fly was not determined, but the area of defoliation provides a measure of distance. Between 1979 and 1981, the area of severe defoliation spread 4 miles (6.4 km) eastward. Moths were also seen over 10 miles (16 km) to the north, southwest, and south of the 1981 defoliated area, which indicates a distance for general population dispersal.

The presence of moths more than 25 miles (40 km) from the visibly defoliated area was probably caused by their transportation on passenger vehicles and logging trucks. The longer distances noted previously most likely resulted from vehicular transportation.

Larval Dispersal

Larvae dispersed four times during their life, including (1) within branch-tree, (2) north-south, (3) south-north, and (4) tree departure. First instars dispersed from the egg mass to the branch tips and usually clustered around a terminal bud. If the egg mass was on the bark of the bole, larvae moved upward on the bole (fig. 7) and then to the branches—a relatively great distance. If they were on the foliage, then the distance to the bud may have been relatively short.

First and second instars also dispersed from northerly aspects to southerly aspects in late fall. In October, densities of recently hatched larvae were relatively equal on all aspects, but by early November, larval densities became significantly greater on the southern aspects. This movement probably continued until over 95% of the larvae resided on southern aspects by mid-December.

As temperatures warmed in April and larvae fed more actively, they became more common on northerly aspects. In May, larval densities were greater on northerly aspects unless virus-caused mortality greatly reduced the population. The greater northern densities are created by the movement from south to north—just opposite of the fall movement.

Final larval dispersal was the emigration of mature larvae from the foliage to the ground via the bole (fig. 8). In June 1983, 10 to 15 were observed descending on one aspect at any one time, and the general larval movement was downward. However, virus-infected larvae moved upward, apparently heading for the upper portions of the crown.

Biotic Mortality Factors

During the course of the outbreak, several mortality factors were noted but only superficially assessed. Insect parasites were important during the egg, larval, and pupal stages; a virus decimated the larval stages in Gen. III; and birds and mammals preyed on larvae, pupae, and adults.

Virus

The most important mortality factor was a virus, probably the same or one similar to the polyhedral virus cited by Wygant (1941). In 1980, the incidence of virus was low and so was mortality. Stelzer's evaluation in 1981 showed 3% of the larvae in DA I were virus-infected (Stelzer 1981). By June 1981 during the late instars, viral-infected larvae were evident throughout DA I where high density larval populations were present during Gen. I and Gen II. In 1983, the virus spread throughout the population and caused a dramatic population decrease. Initial virus prevalence rates for larvae hatching from egg masses collected in September 1982 averaged 5.2% for all areas but reached 11% in DA I and 10% for DA IIa (Bennett and Andrews 1983). Bennett and Andrews (1983) concluded that a viral epizootic was unlikely to develop throughout the entire infestation, although substantial mortality was to be expected in DA I and DA II. A subsequent collection of predominantly second instar larvae in March 1983 indicated an average virus prevalence rate of 36% at 21 days after rearing started, with 77% of the larvae affected (Stelzer 1983). Stelzer expected epizootic infection rates when the larvae reached maturity and correctly predicted population collapse in 1983.

How the virus spreads throughout the population and why it did not drastically reduce Gen. I and Gen. II populations was not determined. Stelzer (1986) hypothesized that virus residues originating from previous, undocumented PM outbreaks remain viable in the soil but not on the foliage. At the initiation of the current outbreak, Gen. I adults acquired small amounts of virus while emerging from the soil and litter. Females contaminated the external surface of the eggs during oviposition. Infected larvae contaminated the foliage during feeding and at death, but foliage also may have been contaminated via dust. Noninfected larvae contracted the virus by their contact with infected larvae or their ac-

tivity in the foliage frequented by the infected larvae. Because larvae usually disperse within the crown at least twice, the probability of contact between infected and noninfected larvae is great, and the incidence of virus-contaminated foliage increases. Eventually, the microenvironment of the PM is thoroughly contaminated such that essentially all of the population becomes infected and the population collapses.

Virus-infected larvae are usually sluggish, fail to respond quickly to disturbance, and usually just remain in the same spot, rather than crawling off when nudged (Wygant 1941). The bodies of dead larvae are flaccid and the integument ruptures easily revealing a liquid interior. Virus-infected fifth instars on saplings frequently move to the terminal portion of the leader and congregate around it (fig. 9). On the larger trees, such larvae move upward, rather than downward as healthy larvae do.

About 50% of the pupae collected in 1980 and 1982 failed to mature. The internal contents, a yellowish-green liquid, lacked any definitive structure. This condition may have been caused by virally infected larvae that formed the exuviae but died before the adults were formed.

Parasites

Egg parasite.—*Telenomus* sp. (Scelionidae) was the most important egg parasite, with parasitism averaging 6% for Gen. II, 4% for Gen. III, and 56% for Gen. IV. Although the latter percentage was based on only 32 egg masses while the other information was based on 350 and 630 egg masses, respectively, the population collapsed during Gen. III so that the number of egg masses available for parasitism in 1984 was relatively low (see table 2). Assuming the *Telenomus* population did not suffer the same degree of population reduction as the PM population, the *Telenomus* adults would be abundant enough to create a high incidence of parasitized egg masses in Gen. IV. Egg mass parasitism was not significant during the first three generations but was significant in Gen. IV or the generation after the population collapsed.

All eggs within each egg mass were not always parasitized—parasitized eggs are black and easily distinguished from nonparasitized eggs. During both Gen. II and Gen. III, 55% of the eggs in parasitized egg masses were parasitized. In Gen. IV, the percent parasitism was not precisely determined, but appeared to be more than 75%. Thus, the level of parasitism remained the same through Gen. II and Gen. III, and then increased significantly in Gen. IV.

Larval parasite.—An unidentified tachinid fly was reared rarely from the fourth and fifth instars, and was not a significant mortality factor.

Pupal parasite.—An ichneumon wasp [*Cratichneumon unifasciatorius* (Cresson)] emerged from reared pupae and caused less than 1% mortality. The ichneumoninae usually oviposit into pupae. Since they habitually search the ground for hosts, this species probably detects and parasitizes pupae, which are close to the surface and not covered by either thick litter or more than an inch of soil.

Predators

Pupae were consumed by the Kaibab squirrel and probably other small rodents, but the mortality was not quantified. Robins (*Turdus migratorius* Linnaeus) picked off moths resting on the shaded portion of the Jacob Lake Inn Service Station during August. The moths are active at night and usually rest in shaded areas during the day. In this case, they had been active around a vapor light near the building corner the previous evening and were resting on the light-colored brick, which contrasted sharply with their gray-black bodies (fig. 6). Each robin alighted momentarily on the building's surface to capture an adult and then flew off. Under forest conditions, the adults would be almost invisible on the tree trunks and, therefore, a less susceptible prey for robins. Other passerine birds were not observed capturing PM adults, nor were bats.

Defoliation

PM defoliation is confined to the older needles, rather than the new shoots and foliage. PM larvae do not destroy the terminal bud or the new growth (fig. 10), even though the fifth instar stage generally coincides with the development of the new growth. Thus, defoliated trees gain foliage during the year of defoliation and the effect on the tree is moderated.

Ponderosa pines, ranging from saplings to the largest dominants, were defoliated. Pinyons were severely defoliated during Gen. III, when the outbreak reached the ponderosa pine-pinyon juniper ecotone. Juniper, Engelmann spruce (*Picea engelmannii* Parry), and white fir (*Abies concolor* (Gord. and Glend.) Lindl.) were not defoliated, even though larvae were observed on them. Whether the larvae starved or emigrated to ponderosa pine was not determined.

Significant defoliation occurred in April, May, and June of the odd-numbered years—1979, 1981, 1983. A small amount of feeding took place in November of even-numbered years and perhaps between December and April. Defoliation became increasingly apparent in late April and May, because the larvae were more actively feeding. In addition, needle consumption increased as the larvae matured, so defoliation became more apparent.

During the outbreak, defoliation varied within the infested area and on individual trees. During Gen. I in 1979, defoliation exceeded 90% on 2,700 acres (1,093 ha) and 50% on 2,400 acres (971 ha). Within stands, defoliation was fairly uniform within the crowns of trees of all sizes. During Gen. II, defoliation again exceeded 90% on all sizes of trees throughout the approximately 19,000 infested acres (769 ha), but defoliation was noticeably less uniform throughout the area, being particularly absent or low on sapling to pole-sized trees in the ravine bottoms and heavy on the ridgetops. This characteristic, noted by Beal (1938) in the Colorado outbreak, is apparently common to pandora moth outbreaks. Defoliation during Gen. III declined as virus-caused mortality

decreased larval populations. Although the extent of the infested area was about double that of 1981, defoliation generally averaged 20% to 30% throughout defoliation area III (DA III) (see fig. 1). Defoliation approached or exceeded 50% on the southern aspect but was less than 10% on the north side, so the average defoliation was 20% to 30%. Around the periphery of DA III, particularly in areas outside DA II where previous generations were either low or nonexistent, defoliation averaged 75% and exceeded 90% on some trees. Defoliation on these trees was fairly uniform on all aspects of the crown.

Effects of Defoliation

The sudden development and spread of the outbreak and the superficially devastating appearance of severely defoliated pines, (fig. 11), as compared to normally green, healthy pines, resulted in a great deal of concern by private landowners, concessionaires, representatives of the local timber industry, and the general public. Of major concern was the perception that the reduction in visual quality due to defoliation would adversely impact tourism and recreational use in the area. Also of concern was the possible adverse effect of defoliation on the Kaibab squirrel (*Sciurus aberti kaibabensis* Merriam), a state-listed "unique species." These squirrels are almost totally dependent on ponderosa pine for every aspect of their survival, and the question arose as to whether they would disappear from areas of severe and moderate defoliation. Another important concern was whether the defoliation would seriously devalue the timber in a sale area coinciding with the northern portion of the defoliation area. Thus, a variety of impacts were possible, including tree growth loss, tree mortality, wildlife alterations, visual quality reductions, and nuisance significance.

Tree Growth Loss

The PM defoliation caused significant tree growth loss. Both growth loss and mortality were influenced by defoliation severity and frequency. The initial evaluation conducted after the 1979 and 1981 defoliations indicated a 25% reduction in basal area (BA) growth over 4 years in stands defoliated twice (DA I), and no significant reduction in stands defoliated once (DA IIa) (Bennett and Andrews 1983) (see fig. 1).

During the outbreak, radial growth for all diameters was about 10% less in DA I and 7% in the area treated with acephate (Bennett et al. 1987). Adjusted radial growth for all diameters increased significantly in the undefoliated area during the outbreak, while growth in DA I and the treated area remained unchanged. Thus, the differences in growth rates among areas were caused more by a lack of increase in the defoliated area than by an actual decrease. Similarly, adjusted basal area growth in the undefoliated area increased significantly during the outbreak, while in DA I it did not change and the treated area increased insignificantly. The difference in growth rates (ca. 10%) between DA I and the undefoliated area was confounded by coincidental intermediate cuts in the defoliated area. The cutting released some of the trees, allowing them to grow faster and thus mitigate growth loss caused by defoliation. The confounding manifested itself differently in trees <14 inches (<36 cm) d.b.h. and trees ≥14 inches (≥36 cm) d.b.h. In trees <14 inches (<36 cm), both radial and basal area growth were not significantly different before and during the outbreak within DA I, the insecticide-treated area, and the undefoliated area. However, growth rates of some trees in DA I increased substantially, which even though insignificantly different, indicated more rapid growth was occurring. In trees ≥14 inches (≥36 cm), radial and basal area growth in the undefoliated area increased significantly, while both rates changed insignificantly in DA I. Thus, trees ≥14 inches (≥36 cm) are more adversely affected by the defoliation than trees <14 inches (<36 cm), and thinning does not appear to mitigate their growth reduction. Based on a 10% decrease in growth rate, the estimated loss in f.b.m. production would be at least 11 f.b.m. per acre (0.07 m^2/ha) per year.

Tree Mortality

Tree mortality was insignificant after two defoliation periods (Bennett and Andrews 1983) and after the outbreak collapsed (Bennett et al. 1987). Mortality in one mistletoe-infected stand was greater than the average for the infested area (see Wagner and Mathiasen 1985, and section on Defoliation-Mistletoe Interaction), especially among trees with a mistletoe rating of 5 or 6. In other mistletoe-infected stands, mortality appeared normal.

The incidence of bark beetle-caused mortality did not increase during or after the PM outbreak. Some bark beetle-caused mortality was noted in DA I; however, the amount was low and not significantly different than in DA II and DA III. The lack of subsequent bark beetle activity may have resulted from the above-average precipitation during the growing seasons of 1981 and 1983 and the PM feeding habits. While Patterson (1929) characterized the defoliated trees as weakened and very susceptible to bark beetle attack, their weakened state during this outbreak may have been moderated by the above-average precipitation, which reduced summer moisture stress. In addition, because PM larvae did not feed on new shoots and developing foliage, the trees recuperated during the summer following defoliation, even though they lost the older foliage during the prior spring months.

Defoliation-Mistletoe Interaction

The presence of southwestern dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopdum* (Engelm.) Hawksworth and Wiens) further accentuated the effect of PM defoliation on ponderosa pine. Radial growth of severely defoliated, heavily infected trees was less than

the radial growth of defoliated, noninfected trees (Bennett and Andrews 1983). Basal area growth was reduced 15% more in infected trees than in noninfected trees (40% versus 25%, respectively), although this difference was manifested only in areas severely defoliated two successive times (DA I) and not in areas severely defoliated once (Bennett and Andrews 1983). Similarly, mortality of severely defoliated, heavily infected trees was greater than for lightly or noninfected trees when the trees were severely defoliated two successive times (Wagner and Mathiasen 1985). Mistletoe-infected trees were less able to tolerate defoliation than noninfected trees (Bennett and Andrews 1983, Wagner and Mathiasen 1985), with the degree of tolerance inversely related to the level of infection (i.e., the mistletoe rating).

Wildlife

District wildlife biologists observed a temporary decline in activity of Kaibab squirrels in moderately to severely defoliated stands. However, normal activity resumed when the stands refoliated, and population levels were not seriously affected. In addition, some bird and mammal activity increased within the defoliated areas.

Visual Quality

Severe defoliation in 1979, 1981, and 1983 reduced the visual quality of stands along a 10-mile (16-km) travel corridor of Highway 89A, a main thoroughfare through the Kaibab National Forest leading to the North Rim of Grand Canyon National Park. Because trees partially refoliated, visual quality was improved slightly within weeks of defoliation. Reduced visual quality lasted 2 to 3 months every other year and by 1985 was no longer evident. The important aspect of reduced visual quality was the inquiries from thousands of area visitors who expressed concern about the high density of larvae and the fate of the defoliated trees.

Sampling and Survey

Sampling

Because no previous sampling methods existed to assess population levels, methods were developed during the outbreak. These methods may benefit managers during future outbreaks.

For assessing the extent of the infestation and its general expansion, a systematic distribution of permanent egg mass plots in and around an infestation should follow a pattern espoused by Bennett (1982). At least 10 plots should be established within the area defoliated by the first generation if that area is 2,000 acres (809 ha) or less. Additional plots should be added in proportion to the additional acres of infestation. Additional plots also should be established for several miles in all directions from the boundary of the initially defoliated area, depending on topography and host type, because the population can spread several miles from one generation to the next. The number of additional plots to be established will depend on the desired accuracy of the infested area boundaries and the number of sample trees per plot. If the extent of the infestation is to be defined on a sectional basis (i.e., 640 acres), then one plot per section is needed. For the additional 13,600 acres (5,504 ha) infested in 1981 (difference between 1979 and 1981), approximately 21 plots would have been needed. Additional accuracy will require more plots in proportion to the desired accuracy, but fewer sample trees per plot may be necessary to make the additional accuracy cost-effective.

Within each plot, the number of sample trees will depend on the number of plots and the sampling objective. Because the variation in egg mass numbers per tree was not generally significantly different among trees of the same size within a small area [0.1 acre (0.04 ha)], 1 tree per plot is sufficient. However, some investigators are uncomfortable with 1-tree plots because of possible zero counts and the lack of measurement of between-tree variation. Before the significance of the different sources of variation were known, Bennett (1982) used 5 trees per plot, which gave good estimates but was excessive in view of the insignificant variation among trees. Multiple tree clusters were used, because they minimized chances of zero counts from a plot. However, the concept of cluster sampling was violated in many stands where the trees were not in close proximity because of stand conditions. The decision for single- or multiple-tree plots thus becomes determined by the sampling objective. If the objective is to precisely determine the presence or absence of the infestation, then single-tree plots are preferable. If the objective is to determine population trend, as well as the presence of the infestation, then 2- or 3-tree plots are preferable. The number of plots to be installed will decide whether 2- or 3-tree plots will be used.

Sample trees preferably should be 30- to 50-foot (9- to 15-m) tall dominants or codominants, so sample branches can be taken 25 to 35 feet (8 to 11 m) aboveground. Trees of this size usually will have straight, foliated branches without excessive dichotomy. Larger trees will have similar egg mass densities, but branches will come from the lower crown, which usually are dichotomous and are not readily suitable for the 9-shoot system. Samples could be drawn from less than 25 feet (8 m) on many trees, but PM egg masses are readily discerned from 10 feet (3 m) away; therefore, to eliminate bias in branch selection, branches should be removed from above 20 feet (6 m).

The basic sampling unit for egg masses was the 9-shoot system. Because egg mass numbers increased linearly with increasing numbers of shoots (Schmid et al. 1983), a 9-shoot sample usually was large enough to minimize zero counts and yet be handled in the basket of a pole pruner. Counts from whole branches or on a 39-inch (100-cm) branch basis will give similar results but are not as efficient.

Based on the rearing of egg masses and defoliation estimates, the following method for predicting defoliation from egg mass counts was developed.

1. Egg mass count averaging ≤1 per 9-shoot sample from trees in a 3-tree plot . . defoliation ≤25%
   Egg mass count averaging >1 per 9-shoot sample from trees in a 3-tree plot 2
2. Egg mass count averaging ≥3 per 9-shoot sample from trees in a 3-tree plot 3
   Egg mass count averaging >1 but <3 per 9-shoot sample from trees in a 3-tree plot . . . Sample two additional trees; if average count for 5 trees still falls between 1 and 3, proceed to couplet 3; if average count is ≤1, defoliation equals ≤25%.
3. Percent parasitism of egg masses ≤10%, virus prevalence rate ≤3% . . . . . . defoliation ≥90%
   Percent parasitism of egg masses ≥50%, virus prevalence rate ≥5% . . . . . . defoliation ≤35%

Because the above method is based on data not primarily designed for the production of the method, its precision is questionable. However, we know that an egg mass-defoliation prediction scheme for the PM is more complicated because of the influence of the virus. During Gen. I and Gen. II, when virus prevalence rates were less than 3%, egg mass counts of three or more per nine shoots signified 90% or greater defoliation—a relatively straightforward relationship. During Gen. III, egg mass counts were similar to those of the previous generations, but virus prevalence rates rose to 36% at 21 days (Stelzer 1983), and the population in such areas later collapsed. Defoliation averaged 20% to 30%, with most defoliation occurring before most of the larvae died. Thus, the incidence of virus needs to be entered in the method unless the user knows what generation is of concern. If PM population always collapsed in the third generation, then a prediction scheme could be relatively simple—high defoliation associated with high egg mass counts for two generations and low defoliation associated with high egg mass counts in the third generation. However, Patterson (1929) implies outbreaks may last four generations, which means that the prediction method would be in serious error if three generations are assumed for every outbreak. This proposed system is independent of the generations and, therefore, more suitable for all outbreaks, even when pest managers may not know what generation is involved.

To assess late instar larval populations during biological evaluations or insecticide projects, either single-tree plots or 3-tree cluster plots are satisfactory (Schmid et al. 1982a). For evaluation of insecticide projects in specific stands or areas ≤50 acres, the systematic distribution of 50 single-tree plots is preferable. This design is just as accurate as the cluster designs, gives better estimates of the population level throughout the specific area, and, therefore, better evaluation of the overall treatment effect. It tends to give more variation to the estimate because of the greater possibility for zero counts. However, most zero counts are created by topographical features, which can be recognized and minimized. The 3-tree cluster also is satisfactory, practically eliminates zero counts, and may be more preferable when large areas ≥100 acres (40 ha) are being evaluated. It does not give the equivalent representation as the single-tree plots but may be more cost-effective, depending on how the plots are located in relation to roads.

Both tree size, sample height above ground, number of branches per tree, and branch form should be as in the egg mass sampling. A 16- to 24-inch (41- to 61-cm) branch should be the sampling unit instead of the 9-shoot sample. This length provides the maximum foliated length that fits into the basket of a pole pruner. Late instar larval numbers are fewer and more easily dislodged than first instar larval numbers, so maximum foliage must be collected.

Larval numbers vary significantly by aspect, so the sampling plan must take equal numbers of samples from each of the four cardinal directions. Because late instar larval numbers are greater on the north aspects, samples drawn mostly from southerly aspects will underestimate larval densities, while samples drawn mostly from northerly aspects will overestimate larval densities. If the sampling is being conducted to evaluate the effect of insecticide treatment, it is desirable to record the aspect for each tree during prespray sampling, so the same aspect can be sampled from that tree during postspray sampling.

Aerial Sketchmapping

To detect PM infestations and evaluate PM defoliation, aerial surveys must be conducted in late June or early July. The North Kaibab outbreak may not have been detected before 1979 because the 1977 aerial survey was conducted in September. By August, PM defoliation is partially camouflaged by the current growth of ponderosa pine, which is unaffected by the PM. Hence, the new shoot growth tends to hide the presence of an infestation or the defoliation from the inexperienced observer, particularly light to medium defoliation characteristic of a beginning outbreak. Bennett personally observed this condition, as exhibited by a subsequent PM infestation in Grand Canyon National Park in 1985, and concluded that had he not known of its presence, he might not have detected it.

In addition to aerial sketchmapping, color-IR photos at a scale of 1:15,000 effectively discerned and more accurately delineated undefoliated, partially defoliated, and heavily defoliated stands (Ciesla et al. 1984). This photography was particularly useful in mapping the extent of different defoliation levels over large acreages and ascertaining the effects of insecticide treatments (Ciesla et al. 1984).

Suppression Strategies

Concerns of local concessionaires, timber industry representatives, and the general public led to demands for an immediate course of action, namely PM suppression. However, very little research had been done in the past to suppress PM populations, and no chemicals were registered for use against these caterpillars. Therefore, several strategies, including prescribed burning and insecticides, were tested to reduce pandora moth populations in the vicinity of Jacob Lake.

Prescribed Burning

Prescribed burning seemed a natural tool for controlling PM populations, because larvae pupate in the litter and first few inches of soil. However, fuel and weather conditions and management policy compromise the effectiveness of this technique to the point that satisfactory mortality usually cannot be achieved.

Late June and early July burning (fig. 12) killed about 60% of the pupae on three different locations, but mortality within each area was variable (Schmid et al. 1981). On average, mortality was greater near tree bases where litter depth and, thus, fuel were greater.

Early summer burning of stands where litter depth is not uniform and deep but is interrupted and sparse will not yield satisfactory mortality. Because a substantial number of larvae pupate where litter is nonexistent or is less than 2 inches (5 cm) deep (Miller and Wagner 1984), the fire does not heat these areas enough to cause mortality. In addition, pupae are deeper in the soil under litter depths of less than 2 inches (5 cm) than they are when litter is 6 to 8 inches (15 to 20 cm) deep and so are not as directly exposed to the fire. Fire management policy also precludes early summer burning, because when fuels are highly flammable and capable of generating high heat, conflagrations also are possible and forest managers are reluctant to burn.

Late September burning caused insignificant mortality to pupae (Schmid unpublished) and was less effective than early summer burning. Mortality near tree bases was not greater than away from tree bases. The effectiveness of burning in September and October (fall) also is hindered by fuel conditions. Fall burning is preferred by forest managers, because fuel and weather conditions are more conducive to slow-burning, easily controlled fires. However, the greater soil moisture caused by fall precipitation and the cooler air temperatures inhibit the fire from killing the pupae via direct burning, lethal temperatures, or dehydration. The very conditions that make fall burning more favorable to forest managers makes them unfavorable from a PM control standpoint.

Insecticides

Before 1970, insecticides specifically effective against the PM were unknown. In 1971, Lyon reported on insecticides tested against PM larvae in the laboratory and determined pyrethrins were good candidates for field testing. From 1971 to 1980, no further testing was conducted, so no effective compound was registered for PM control when the North Kaibab outbreak erupted.

In the fall of 1980, field testing of four chemicals via an aerial application simulator showed acephate and permethrin to be significantly more effective than carbaryl or dimilin against first instars on saplings. Based on these tests, acephate was selected for use in the pilot test against third and fourth instars in May 1981. Acephate applied at the rate of 0.75 pounds per acre (0.86 kg/ha) yielded mixed results in five spray blocks. Unadjusted mortality averaged 56% in three blocks and 21% in the other two blocks (Bennett and Ragenovich 1982). However, in the check areas, mortality was 20% during the same time period, so adjusted mortalities attributable to the treatment were 36% and 1%, respectively. The overall mortality for the 1981 project was well below the acceptable level. Substantial snowfall within 12 hours after application caused poor mortality in two blocks and probably influenced mortality in the other three blocks. These results led to the stipulation that future insecticidal treatment would be conducted only when suitable weather conditions exist the day of application and no precipitation is forecast for the following three or more days. In addition, treatment of small blocks, such as the 500- to 700-acre (202- to 283-ha) parcels treated in 1981, does not insure protection for more than one generation. In 1982, egg mass densities in the treated blocks averaged 2.7 per nine shoots (Bennett and Andrews 1983), which indicates adults may have immigrated into a treated area to create pretreatment population levels.

Because of the poor results and the potential need for another insecticide treatment in 1983, further testing was conducted in October 1982. Acephate (Orthene Forest Spray) reduced first and second instar larval populations about 50% within 12 days after spraying in October, while dimilin, malathion, and carbaryl were not different than the control (Ragenovich et al. 1986). After 213 days, both acephate and dimilin were equally effective, while malathion and carbaryl were less effective.

Because acephate was most effective in the 1982 tests, it was applied again over 650 acres (263 ha) surrounding the Jacob Lake Inn on May 20, 1983. The objective of this treatment was to prevent severe defoliation in areas of heavy visitor use. Following treatment, defoliation was generally less in the treated area than in the nontreated, infested areas (Bennett et al. 1984). While both the 1981 and 1983 insecticide programs reduced populations and provided foliage protection where visual quality was concerned, they had little or no effect on the overall course of the infestation.

Two options exist for insecticide treatment of PM populations—a fall treatment against first and second instar larvae and a spring treatment against mainly fourth instar larvae. The fall treatment usually benefits from more precipitation-free days that are more satisfactory for insecticide application, although by late October, the possibility of suitable weather substantially lessens. Other advantages of the fall treatment are that early instar larvae succumb to lower dosages of insecticide than are needed to kill late instar larvae (see Robertson 1983a, 1983b), and fall treatment should prevent at least 25% of the defoliation that usually occurs between fall and spring. One disadvantage of fall treatment is that a late September-early October treatment will encounter substantial numbers of unhatched egg masses, so short-lived insecticides may not affect subsequently emerging larvae, whereas a May or spring treatment benefits from the presence of actively feeding larvae and no unhatched viable egg masses.

Silviculture

Because stand structure and tree size do not seem to influence female oviposition behavior or larval survival, silvicultural activities have little potential for suppressing outbreaks. However, silvicultural treatments that maintain desirable stocking levels and reduce the incidence of dwarf mistletoe will reduce growth and mortality losses. Intermediate thinnings at the start of the outbreak apparently mitigated growth impact (Bennett et al. 1987).

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A pandora moth outbreak in Arizona was studied from 1979 to 1985 to determine the moth's life cycle, densities, and distribution of life stages, larval and adult behavior, effects of the defoliation, sampling procedures, importance of biotic mortality factors, and the effectiveness of insecticides. This report summarizes the available published and unpublished information on the outbreak.

Keywords: Pandora moth, *Coloradia pandora*, insect outbreaks, ponderosa pine

Top: V instar larva. Bottom: Prepupa and pupa in uncovered pupal site.

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky Mountains

Southwest

Great Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

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Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

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Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

United States Department of Agriculture

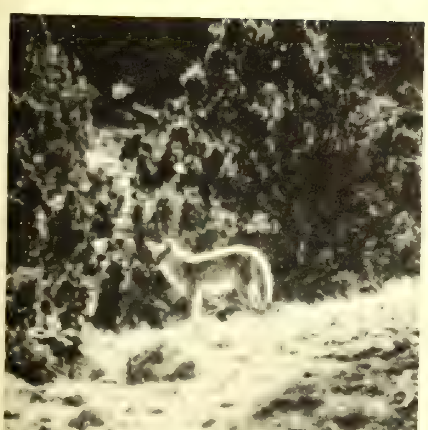
Forest Service

Rocky Mountain Forest and Range Experiment Station

Fort Collins, Colorado 80526

General Technical Report RM-154

Eighth Great Plains Wildlife Damage Control Workshop Proceedings



April 28-30, 1987
Rapid City, South Dakota

Uresk, Daniel W.; Schenbeck, Greg L.; Cefkin, Rose, technical coordinators. 1988. Eighth Great Plains wildlife damage control workshop proceedings. General Technical Report RM-154. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 231 p. [Listed also as Publication No. 121, Lincoln, NE: Great Plains Agricultural Council.]

Abstract

These proceedings consist of more than 40 presented papers on damage caused by many different animals. Panel presentations that followed two special sessions--one on prairie dogs and related small mammals and another on ways to enhance waterfowl production--are also included. In addition to information on mechanical and chemical control methods, the ecosystem processes involved are considered.

Keywords: Prairie dogs, waterfowl, coyotes, rodents, bird repellents, predacides, rodenticides

Pesticide Precautionary Statement

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U.S. DEPARTMENT OF AGRICULTURE

USDA Forest Service
General Technical Report RM-154

January 1988

Eighth Great Plains Wildlife Damage Control Workshop Proceedings

April 28-30, 1987
Rapid City, South Dakota

Technical Coordinators:

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Sponsor:

Great Plains Agricultural Council, Wildlife Resources Committee

In cooperation with:

USDA Forest Service, Rocky Mountain Forest and Range Experiment Station
USDA Forest Service, Nebraska National Forest
USDA, Animal and Plant Health Inspection Service, Animal Damage Control
South Dakota Cooperative Fish & Wildlife Research Unit
South Dakota Department of Game, Fish & Parks
South Dakota Department of Agriculture
National Park Service

Preface

More than 200 people attended the Eighth Great Plains Wildlife Damage Control Workshop in Rapid City, South Dakota. The workshop brought together field technicians, managers, administrators, researchers, educators, students, legislators, and extension and industry representatives to further technology and information transfer. In addition to a general session on damage caused by many different animals, two special sessions were held: (1) prairie dog management and control, and (2) predator management and control to enhance waterfowl production. Both of these topics are currently high-interest issues on the northern Great Plains, the site of this workshop. Each of these sessions consisted of individual presentations followed by panel/audience discussions. A well-attended field trip to review black-tailed prairie dog management on the Buffalo Gap National Grassland and Badlands National Park brought the workshop to a close. These proceedings document this workshop.

Rapid publication of these proceedings was facilitated largely by the excellent efforts of the authors (and the typists!) in preparing the manuscripts, most of which we received camera-ready. Since papers are, essentially, being printed as received, each contributor is responsible for the accuracy of his or her paper; opinions expressed by the authors may not necessarily reflect the policy of the U.S. Department of Agriculture.

We extend our thanks to Steve Denison, Robert Hodorff, and Lisa Nold for technical and operations assistance during symposium sessions. Shary Kennedy and Susan Scott graciously typed final drafts of many manuscripts. We appreciate the time and effort spent by personnel of various sponsoring agencies in making this workshop a success.

Finally, we would like to express appreciation to the Rocky Mountain Forest and Range Experiment Station, Rapid City, SD; the Rapid City Chamber of Commerce; and to the Nebraska National Forest, for being excellent workshop hosts.

We believe the proceedings of this workshop will serve as a valuable vehicle for continued improvement in the effectiveness, soundness, and professionalism of the field of wildlife damage control and management. It is our hope that the success of this workshop will provide further incentive for the Great Plains Agricultural Council to continue its promotion of similar workshops in the future.

Daniel W. Uresk, Chairman

Greg Schenbeck, Co-Chairman

Contents

Welcome from the Great Plains Agricultural Council[1]

Robert L. Storch[2]

On behalf of the Great Plains Agricultural Council and other sponsoring agencies, I want to welcome you to the 8th Great Plains Wildlife Damage Control Workshop. From the very first session that was held in 1973 at Manhattan, Kansas, this workshop has consistently enjoyed a high level of success, and we believe this year's effort will be no exception. Being approximately a year and a half since the last workshop in San Antonio, we were initially concerned about the amount of interest that would be shown in this year's workshop. However, in looking at the number and quality of the papers that are identified in the program's agenda and considering the number of people who are here today, it is obvious our concerns were unfounded and interest in the Great Plains workshop remains high.

At this time, I would like to recognize those who have contributed significantly to the planning and organization of this year's workshop. First I want to acknowledge Ardell Bjugstad, project leader for the Forest Service research unit here in Rapid City, for being instrumental in bringing the workshop to South Dakota. Ardell has also arranged for much of the financial assistance that is so necessary for a meeting of this size. Dan Uresk, who is a member of Ardell's staff, and the rest of the program committee have spent a considerable amount of time planning and organizing this year's workshop. If you will look at the inside cover of the program agenda, you will see the list of all individuals and agencies responsible for this workshop, and I want to thank each of those individuals and their employing agencies for their participation and support.

I believe it's appropriate to say a few words about the Great Plains Agricultural Council. The Council is made up of selected agencies of the U.S. Department of Agriculture and the Cooperative Extension Services of the Land Grant Universities in the 10 Great Plains states. Its present organization dates back to 1946, however, its roots go back to the 1930's. The purpose of the Council is to provide an organization for effective cooperation and coordination in responding to current and emerging issues of importance to Great Plains agriculture. In fulfilling its mission, the Council provides a forum for technology transfer and cooperation on activities that effect the natural resources of the Great Plains. Six committees perform much of the Council's work, and relative to this workshop, the Wildlife Committee is the sponsoring entity.

The agenda for the next two days is full. There are topics ranging from crop depredation to control and management of rodent and predator damage. However, in addition to the subject areas that have been traditionally covered at previous workshops, we have also included topics dealing with predator management and control as they relate to waterfowl production. Waterfowl managers across the Northern Plains continue to be active in this area and the program committee felt that the technicians and researchers involved in this form of wildlife management should be given the opportunity to share their knowledge with us. We're confident that this will add a new dimension to our program. We hope that you agree.

If I may, I would like to take a few minutes to philosophize with you. During the last several years I have been responsible for the administration of several units of the National Forest System here in South Dakota and Nebraska. From my observations, I can say the Northern Great Plains, like many other regions, is in a state of change. In agriculture, we see change. On many economic fronts, change is the norm rather than the exception. This is also true in the area of natural resource management. In my line of work, in the management of the National Forest System, more and more of the public are expressing their needs and concerns and requesting involvement in the decision making process. We, in the Forest Service, find ourselves in a position of closely scrutinizing every management decision that has the potential of affecting the public. We also are being required to review decisions made in the past to determine if those decisions remain in the best interest of the public today. I believe this increase in public involvement in natural resource management is the sign of the times, as well as, a sign of the future, especially when public funds and/or lands are involved. Now, how does all this relate to wildlife damage management and control? Again, I speak first hand. The amount of public inquiries on items such as predator and rodent

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[1] Presented at the Eighth Great Plains Wildlife Damage Control Workshop, Rapid City, South Dakota, April 28-30, 1987.

[2] Robert L. Storch is Forest Supervisor, Nebraska National Forest, Chadron, Nebraska.

management on National Forest System lands has grown substantially. As a result, the decisions I make today are made following more deliberation than those I made when I first arrived on the job. Accordingly, I would recommend that agencies and personnel involved in wildlife damage management and control closely monitor their programs to ensure these programs are adequately responding to the needs and concerns of the public.

The monitoring and evaluation of the wildlife damage programs on the National Forest System is vitally important. To assist us with this task, we use the Wildlife Society's recent Position Statement on wildlife damage control. It is used as a guide and an evaluation tool. I believe this position statement provides an excellent basis for evaluating ongoing ADC programs. I also strongly believe this approach is supported by the majority of the American public. I will not take time to review the individual points identified in this Position Statement, however, I encourage those of you involved in wildlife damage programs to familiarize yourselves with it.

In closing, I call your attention to the excellent papers that open the workshop this morning. I want to highlight a couple of them that are specific to the State of South Dakota. The presentation by Chuck Post will describe the diversity of this state in terms of the land, the wildlife, and its people. From this you will acquire the appreciation of the complexity of the issues dealing with wildlife damage management and control that are occurring In Al Miller's overview of the ADC program in South Dakota, you will see a very complete program. A program that not only consists of a successful statewide network, but one that has multi-agency involvement and is strongly committed to research.

Again, I welcome you to this workshop and hope it will provide a valuable learning experience to you. I know it will be for me. Thank you.

South Dakota—Its History, Land, and Wildlife[1]

Chuck Post

South Dakota, duh KOH tuh, was named for the Dakota, or Sioux Indians who lived in this region before the white man came. In addition to the Sioux, two other tribes lived in the area before the white man. The Arikara built permanent homes and raised crops while the Cheyenne lived mostly by hunting. The wandering Sioux were hunters and warriors who moved from place to place following the great herds of bison.

In 1862 all the land that was drained by the Mississippi River system was claimed for France. South Dakota was included because the waters of the Missouri River system flow into the Mississippi.

The French-Canadian explorers, Francois and Louis Verendrye were the first white men known to have visited the state. In 1743 the brothers buried a lead plate near the site of Ft. Pierre to prove they had been here. School children found the plate in 1913.

In 1762, France gave Spain the land and in 1800 Spain ceded it back to France. In 1803 the United States acquired South Dakota as part of the Louisiana Purchase.

In 1781, Pierre Dorion, a Frenchman, arrived in the lower James River Valley near what is now Yankton in the far southeastern part of the state. He was the first white man to permanently settle in present day South Dakota. The American explorers Lewis and Clark crossed the state on their way west in 1804, and again on their return in 1806. Their reports attracted many fur traders to the area. A French fur trader Joseph La Framboise, established a trading post in 1817 at the junction of the Missouri and Bad rivers where Fort Pierre now stands. This was the first permanent settlement in the region.

The first important Indian encounter occurred in 1823, when the Arikara attacked a trading party led by General Ashley. The federal government sent an army detachment to punish the tribe. The Sioux joined in crushing the Arikara.

The arrival of the Yellowstone at what is now Fort Pierre, in 1831 proved that steamboats could travel up the Missouri River. This development brought new fur traders to the region. Soon the number of fur bearing animals began to decrease, and the trade had almost ended by the 1850's.

Agricultural settlement began in 1856, when pioneers from Iowa and Minnesota came to an area near the present day Sioux Falls to raise crops.

In 1861 Congress created Dakota Territory. It consisted of present day South and North Dakota, and parts of Montana and Wyoming.

In 1874 Colonel George Custer led a military expedition into the Black Hills. He was to investigate reports of gold in the mountains. The soldiers discovered gold near the present day town of Custer, and the news brought the first rush of prospectors to the area in 1875. After discovery of the Great Homestake Lode in 1876, thousands of miners flocked to the Black Hills. Deadwood, the center of placer mining operations, became a notorious wide-open mining town that echoed the names of Calamity Jane and Wild Bill Hickok.

The invasion of the Sioux Indian lands by the prospectors and other white men caused a series of Indian uprisings led by Crazy Horse and Sitting Bull. In 1876 Crazy Horse surrendered, Sitting Bull escaped into Canada, and all the Indians left the Black Hills. The Indians agreed to give up the Black Hills region, and most of the Sioux surrendered their arms and settled on reservations west of the Missouri River.

The discovery of gold and building of railroads speeded settlement during the 1870's and 1880's. In 1889 South Dakota became a state. The population at the time numbered about 300,000.

Little development took place in the first few years due to severe drought. However, the early 1900's brought rapid progress. Thousands of homesteaders poured in and by 1900 400,000 people lived in the state. By 1930 the population grew to 683,000.

[1] Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop, Rapid City, South Dakota, April 28-30, 1987.

[2] Chuck Post is Information and Education Supervisor, South Dakota Department of Game, Fish, and Parks, Pierre, South Dakota.

The 1930's began with the worse drought and grasshopper plague ever experienced in the state. The drought, accompanied by dust storms lasted for 10 years, except for some relief in 1932 and 1935.

After 1940, high farm prices and plentiful rain brought prosperity back to South Dakota.

South Dakota is full of distance. It has miles of fertile farm land and grassy, windswept prairie that stretch as far as the eye can see. Pastures cover more than half the state, and fields of crops take up most of the rest of the land. The state ranks among the leaders in the production of corn, rye, oats, spring wheat, flax seed, hay and a variety of grass seeds. South Dakota is also a leading beef-cattle state. Farmers raise livestock on large ranches on the western plains and on smaller farms in the east. The rich soil in the eastern section supports an abundance of crops, part of which are used for livestock feed.

The southeast corner of the state contains the most fertile soils, and it is here farmers raise corn, soybeans and other cereal grains. Most of the eastern part of the state is flat except for river valleys and coteaus. The middle section and most of the western part of the state is referred to as the Great Plains. The land is generally flat but broken by deep river valleys and buttes. In the far west there are the rugged, granite mountains of the Black Hills. This region has towering rocks and forests of pines and spruce. The Black Hills are well known as a tourist attraction, and for rich mineral deposits and lumber.

The fertile soil is the state's greatest natural resource. The state also has rich mineral deposits, and some forest resources consisting mainly of ponderosa pine, spruce and cottonwoods.

The glacial till that covers much of the state east of the Missouri River produces loamy soils, nearly black in color. Much of the soil west of the Missouri River consists of eroded shale.

The Black Hills provides most of the state's mineral wealth. The vein of gold ore discovered at Lead in 1876 has reserves of more than 14,000,000 tons. The ore contains some silver. The Black Hills area also has beryl, feldspar, columbite-tantalite, gypsum, iron ore, limestone, lithium, clays and mica. Uranium deposits lie chiefly in the southern end of the Black Hills.

Forests cover about 2,000,000 acres, mostly in the Black Hills. The trees include ponderosa pine, aspen, spruce and cedar. Cottonwoods can be found along the rivers and creeks in the rest of the state.

The Missouri River crosses the middle of the state and drains all but the northeast corner. Its western tributaries include the Grand, Moreau, Cheyenne and White rivers. The James, Big Sioux and other smaller rivers join the Missouri in the east.

The natural lakes in the northeast part of the state were formed during the Ice Age, when drainage water was dammed up behind glacier-piled earth.

The Missouri, once a wild and muddy river, has since been tamed by four South Dakota dams--Oahe, one of the largest earthen dams in the world, near Pierre; Big Bend at Ft. Thompson; Ft. Randall at Pickstown and Gavins Point near Yankton. Huge reservoirs have now been created behind each of these dams.

The abundance of game on the prairie before the encroachment of the white man's civilization staggers the imagination. The prairie grasses never grew to a climax vegetation because the numbers of buffalo were so great.

Today, it's difficult to grasp the tremendous influence the buffalo had on the life history of many species. The prairie dog, antelope, wolf and grasshoppers flourished with the buffalo. Deer, rabbits and sharptail grouse maintained, at best, a precarious existence. Only in the Black Hills and along the heavily timbered river bottoms did the whitetail deer succeed. The mule deer, because of his preference for precipitous terrain and badland areas, was able to hold his own, but elsewhere, through the thousands of square miles of rolling prairie, the mule and whitetail deer were found in limited numbers. Deer became the dominant big game animal only after the buffalo was gone, but deer were abundant only briefly before they too were decimated by the hunters.

The buffalo herds which ranged from Texas to Montana and from the Mississippi River to the Rocky Mountains numbered between 65 and 70 million animals at their peak.

"I have seen herd after herd stretching over a distance of eighty miles, all tending in the same direction..." wrote Deb. R. Keim, a pioneer writer, of the vast herds.

Migrating ducks and geese darkened the skies. Sharptail grouse were found extensively, until land use changes caused the prairie chickens to flourish, replacing the sharptails. Elk, deer, quail, bear, turkeys, antelope, Audubon's bighorn sheep, wolves, mountain lions--call the roll--they were all here.

Before 1800 South Dakota's antelope were estimated to exceed 700,000. No estimate we know of has been made on the other wildlife, which also flourished.

The philosophy of a hundred years ago was one of nearly complete freedom. The land was free, the game was free and thought to be inexhaustible, and nearly every man was a law unto himself. Wildlife was needed for man to subsist, and the prairies provided it in abundance.

Perhaps it was necessary for the buffalo herds to be reduced to nothingness. Certainly agriculture and ranching could not co-exist with millions of buffalo. New land use drove the prairie chickens away, but made it possible for the pheasant to flourish.

These are things to consider. It may be easy to speculate on the rightness or wrongness of our predecessors; it may salve our consciences for our faults in the present day if we view the foibles of our fathers--it is also fruitless. History is irrevocable--only the future is worth speculation.

Beaver were the first to be capitalized upon by the fur traders, but after the demand for furs grew and the river transportation system improved, the herds of buffalo were next.

Cargoes of Missouri River steamboats came to be made up largely of beaver pelts for gentlemen's hats and buffalo hides for fashionable carriage robes. For half a century, nearly $100,000 a year went down the Missouri in the form of hides and furs.

After the Civil War, the railroads came, and with them, men like Buffalo Bill Cody and Billy Comstock who made their living supplying buffalo meat to railroad crews. Towns sprang up along the rail heads, named after places in the East, after railroad officials, and after topographical peculiarities.

The gandy-dancers must have dined like kings because the hunters took only the humps, tongues and hindquarters of the buffalo. It's estimated the Cody alone left 3 million pounds of meat to rot on the prairie.

The fate of the buffalo was nearly sealed when the major railroads were completed in 1872-73. Buffalo hunters were thrown out of jobs. The settlers continued to push west, moving the Indians before them. The Indians didn't push without resistance, though. The army showed a remarkable degree of incompetence in some of the Indian campaigns, and sought other means for quashing the Indian threat.

Other means were available. Certain military and railroad officials believed the Indians could be subdued if they had no food, and the buffalo hunters were employed again, this time to pursue a program of relentless slaughter throughout the Missouri Valley.

By 1881, the job was practically completed with a great kill of buffalo on the Grand River near Lemmon. During the next few years, remnants of the herd were searched out and killed.

The professional hunters were again organized as efficiently as a company of soldiers. In a large outfit, three or four hunters could kill enough animals to keep thirty or forty men busy skinning and hauling hides and meat, and running the camp. Cody alone had killed 4,280 buffalo in an 18-month period. A single firm in Glendive, Montana shipped out more than 250,000 buffalo hides, the majority of which were bought in the Dakota Territory following the Grand River kill.

The Grand River hunt virtually marked the end of the buffalo on the open range. Carcasses were left strewn over the prairie for more than ten miles near Lemmon, and later bird hunters were to wonder at the expanse of bleaching bones.

The hunt had the desired effect. Except for sporadic outbreaks, Indian resistance had been crushed efficiently. It was the first time America had seen the concept of total war carried out against a whole hostile population.

Settlers and homesteaders and "sportsmen" poured into the Dakotas, and during the period from 1865 to 1900 what had been unimaginable abundance of game became a conscience-haunting scarcity.

The unremitting pressure on the game brought the Territorial Legislature to pass the first law regulating hunting in 1875.

Elk, deer and antelope fared little better than buffalo at the hands of the hunters. Elk were so nearly exterminated in South Dakota they had to be restocked from Wyoming. Nearly every cargo of buffalo hides that went out of the Dakota Territory contained pelts of other animals.

As buffalo became scarce, deer flourished, but professional hunters turned their attentions more and more to the smaller animals.

An era was dying.

As late as in the 1880's, Ernest Thompson Seton, the famed naturalist from the East, reported seeing between 8,000 and 9,000 antelope a day in the Badlands. But these days were numbered by the avarice of the market hunter and the "real quill" sportsmen and the rancher's fence.

Nor was the slaughter to be confined to big game. Anything wild that flew, crept or ran was something to be killed, either for profit or the pleasure of blood lust.

THE BLACK HILLS JOURNAL, on December 21, 1883, said:

"Some parties brought a load of grouse to town yesterday. They disposed of them readily and at a good price."

The West River country and the Black Hills weren't the only areas of the state touched by the wanton slaughter. Game had been abundant in the East River part of South Dakota, and had been killed there as heedlessly as any other place.

Settlement had brought a temporary burgeoning of the number of grouse and prairie chickens because of the additional food supply in the corn and grain fields. Because of this temporary increase, prairie chickens and grouse were plentiful about a decade longer than the buffalo. More intensive cultivation would eventually destroy their natural range and nesting habitat, however.

For almost a generation, the area of the Great Plains that included eastern Dakota was known as "the chicken country." During the period from 1870 to 1900, hunters had only their consciences to be their guides, and the market hunter reaped a rich harvest.

Barrels and boxes of prairie chickens consigned to game markets in Eastern cities were a common sight on depot platforms throughout the area. Millions of chickens and grouse were killed, and the settlers were indifferent to or assisted in the slaughter.

The ducks, geese, plover and brant that obscured the skies belonged in the same category.

Nature had shown an awesome regenerative power, through, and even the turning of the prairies and hills into a charnel house did not entirely wipe out the game. Changing land use--the logging of the forests, building of roads and rail lines, damming streams, breaking the native sod and overgrazing with cattle--all served to destroy the habitat of wildlife. Hunters had killed the last grizzly bear in the Black Hills about 1885, and fewer than 800 buffalo remained in the United States, and most of them in captivity. The Virginia turkey was almost gone.

And then nature decided to help man in the revel.

It set the stage with severe blizzards during the winter of 1880-81.

Nature's finishing blow to what man had begun brought home a sudden realization that wildlife and fish were not something merely to be exploited for the market or slaughtered needlessly. At least, this realization came home to the more intelligent members of the community.

By the end of the 19th century the conservation movement had begun in earnest. After the turn of the century, game laws were to become more and more stringent. And by 1909 the Department of Game, Fish and Parks was created.

Since the turn of the century, wildlife populations have had there ups and downs.

The drainage of thousands of acres of wetlands has affected waterfowl, furbearers, and other wildlife that depend on wetlands for their existence. The breaking of prairie sod has shown its influence on sharptail grouse and prairie chickens. The damming of the Missouri River has almost led to the demise of the paddlefish, and the encroachment of pine and civilization upon the Black Hills has not benefited elk and whitetail deer. But overall, South Dakota is still blessed with abundant and varied species of wildlife.

The wetlands of the northeast are very critical to North American duck production. South Dakota ranks second in duck production throughout the continental United States. The northeast lakes offer some great fishing for a variety of sport fish. Snow geese build up in huge numbers in the fall at Sand Lake National Wildlife Refuge. The eastern half of the state is also home to the ringneck pheasant, Hungarian partridge, bobwhite quail, red fox, muskrat, mink, beaver, cottontail rabbits, red squirrels, and an excellent population of whitetail deer.

The Missouri River reservoir system offers some of the finest walleye fishing in the nation. And for trophy northern pike and chinook salmon, the largest reservoir on the river system, Lake Oahe,offers both. Each fall thousands of migrating Canada geese and mallard ducks stop along the river on their way south.

The western prairies are homes to the sharptail grouse, prairie chicken, mule deer and pronghorn antelope. Wild turkeys frequent the wooded river and creek bottoms and coyotes and prairie dogs can be found throughout the area. Water is at a premium in this western country, and when you find it you can bet it will be filled with largemouth bass.

The Black Hills has a variety of wildlife. The lakes and streams are trout country--browns rainbows, and brooks. Some of the large reservoirs have good walleye fishing. Whitetail and mule deer are scattered throughout the timbered area. Rocky mountain bighorn sheep are found in Custer State Park, and mountain goats frequent the craggy, granite outcroppings of the high mountains. Elk herds offer hunting recreation in the fall and Custer State Park has one of the largest buffalo herds in the nation.

South Dakota is a land full of distance and variety. From its cornfields of the east to the

mountains of the west it is a land that man has sweated and toiled to put under his control. It's a land steeped in western heritage. Cowboys still saddle horses and ride the range rounding up cattle. Rodeos are as popular as football games, and once you cross the Missouri River heading west most everyone you see will have a Stetson on his head. South Dakota is noted for many things. Mt. Rushmore and pheasants may be numbers one and two, but it's friendly people are really the most important asset of the state.

An Overview of the South Dakota Animal Damage Control Program[1]

Alvin L. Miller[2]

Animal Damage Control in South Dakota is a very comprehensive program. The program's objective is to reduce agricultural loss caused by predators, nuisance animals, rodents, migratory birds and waterfowl. It involves the cooperation of several federal, state and county agencies as well as landowners and in turn requires very close coordination of these various entities in order to successfully achieve our objective. Operational control, extension services, research and educational programs are all important facets of such a comprehensive program.

Animal Damage Control is a vital program in South Dakota because of its direct relationship to agriculture and the agricultural economy. Agriculture is the number one industry in the State of South Dakota. According to a nationwide agricultural census, South Dakota ranked 5th in number of beef cattle and 5th in sheep. South Dakota also ranks among the top ten states in the production of corn for grain, oats, wheat, barley, rye, flax seed, sunflower seed, hay and alfalfa (see table 1). The vast topographical difference from one end of the state to the other accounts for a wide diversity in agricultural practices. These same topographical differences provide a wide variety of habitat conditions that become food and shelter for our wildlife populations. When wildlife is forced to coexist with man in his environment, problems often arise. These problems can be caused by a variety of things like a disease such as rabies, the destruction of crops or the predation of livestock. Resolving these wildlife/agricultural conflicts is the responsibility of the Animal Damage Control Program in South Dakota.

The Animal Damage Control responsibilities are shared by a number of different agencies and organizations. Each plays an important role in making up one of the most comprehensive Animal Damage Control programs in the nation. The South Dakota Department of Game, Fish and Parks has the largest role in this Animal Damage Control responsibility. This agency is responsible for the management of all game animals, birds, fish and furbearers within the state. Much of the animal damage problems that occur are caused by a wildlife species that comes under this management responsibility.

The Game, Fish and Parks Department has a special unit known as the Animal Damage Control section. This unit consists of a supervisor and one assistant supervisor, one secretary, sixteen full time extension trapper specialists, two pilots and four part time trappers. The primary responsibility of this unit is to reduce or eliminate agricultural losses caused by predators, nuisance animals and rodents.

The field staff are all stationed in strategic locations so as to best serve the needs for Animal Damage Control. Workloads have changed in recent years causing an increased need for manpower in the eastern part of the state. This need was addressed by adding one full time and two part time trappers (April - October) east of the Missouri River. Currently we have eleven full time and two part time trappers stationed in the western half of the state and five full time and two part time trappers stationed in the eastern half of the state. The one west river part time works from April - October. The second one serves a dual role. This person works two months during denning season (April - May) then serves as rodent control specialist August - November.

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[1] Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop (Howard Johnson's, Rapid City, South Dakota, April 28-30, 1987).

[2] Alvin L. Miller is Supervisor of Animal Damage Control, South Dakota Department of Game, Fish and Parks, Pierre, South Dakota.

Table 1.--State rankings, South Dakota and ten leading states--1984.

CROP PRODUCTION - 1984

ITEM	UNIT	1	2	3	4	5	6	7	8	9	10	S.D. Rank
CORN FOR GRAIN	MIL. BU.	IOWA 1,444.8	ILL. 1,247.2	NEBR. 799.3	IND. 705.5	MINN. 689.1	OHIO 460.2	WISC. 344.5	MICH. 220.1	S.D. 186.3	MO. 154.4	9 186.3
OATS	MIL. BU.	S.D. 86.8	MINN. 78.0	WISC. 53.8	N.D. 50.0	IOWA 47.4	MICH. 21.7	PA. 16.0	NEBR. 15.0	OHIO 13.2	ILL. 10.7	1 86.8
ALL WHEAT	MIL. BU.	KANS. 431.2	N.D. 284.2	OKLA. 190.8	WASH. 160.4	TEXAS 150.0	S.D. 126.0	MINN. 120.7	COLO. 115.3	MONT. 104.7	MO. 84.1	6 126.0
WINTER WHEAT	MIL. BU.	KANS. 431.2	OKLA. 190.8	TEXAS 150.0	WASH. 148.8	COLO. 110.4	MO. 84.1	NEBR. 81.0	ILL. 70.4	MONT. 67.0	OREG. 66.2	12 61.2
DURUM WHEAT	MIL. BU.	N.D. 78.6	CALIF. 9.4	ARIZ. 7.2	MONT. 3.6	S.D. 3.1	MINN. 1.6	-- -	-- --	-- --	-- -	5 3.1
OTHER SPRING WHT.	MIL. BU.	N.D. 183.6	MINN. 103.7	S.D. 61.7	MONT. 34.1	IDAHO 24.7	WASH. 11.6	COLO. 4.9	OREG. 2.8	UTAH 1.8	NEV. 1.2	3 61.7
BARLEY	MIL. BU.	N.D. 153.7	IDAHO 88.4	WASH. 63.7	MINN. 61.8	MONT. 59.1	S.D. 30.3	CALIF. 29.0	COLO. 20.2	OREG. 17.4	UTAH 11.6	6 [illegible]
RYE	MIL. BU.	S.D. 10.8	MINN. 6.7	N.D. 5.4	GA. 1.8	NEBR. 1.3	OKLA. .7	MICH. .6	PA. .6	N.C. .6	S.C. .5	1 10.8
FLAXSEED	MIL. BU.	N.D. 4.9	S.D. 1.5	MINN. .7	-- -	-- -	-- --	-- --	-- --	-- -	-- --	2 1.5
SORGHUM FOR GRAIN	MIL. BU.	KANS. 216.8	TEXAS 209.4	NEBR. 121.6	MO. 91.8	ARK. 42.5	MISS. 23.7	TENN. 20.8	ILL. 19.7	S.D. 18.6	OKLA. 18.0	9 18.6
SOYBEANS FOR BEANS	MIL. BU.	ILL. 288.6	IOWA 264.6	MINN. 172.9	IND. 150.1	OHIO 137.6	MO. 108.7	ARK. 101.4	MISS. 76.8	LA. 64.3	NEBR. 63.8	16 31.3
SUNFLOWER SEED	MIL. LBS.	N.D. 2,749.9	S.D. 633.5	MINN. 313.1	TEXAS 48.1	-- --	-- --	-- --	-- --	-- --	-- --	[illegible] 633.5
ALL HAY	MIL. TONS	WISC. 12.8	MINN. 8.4	S.D. 8.1	CALIF. 7.9	IOWA 7.9	NEBR. 7.5	MO. 6.3	KANS. 6.1	TEXAS 5.4	N.Y. 5.4	3 8.1
ALFALFA HAY	MIL. TONS	WISC. 11.3	CALIF. 6.6	IOWA 6.6	MINN. 6.5	S.D. 5.7	NEBR. 5.1	MICH. 4.6	IDAHO 3.9	KANS. 3.3	ILL. 3.0	5 5.7
ALL OTHER HAY 1/	MIL. TONS	MO. 5.1	TEXAS 4.6	KANS. 2.9	N.Y. 2.6	KY. 2.6	S.D. 2.4	OKLA. 2.4	PA. 2.4	NEBR. 2.4	TENN. 2.2	6-9 2.4
POTATOES	MIL. CWT.	IDAHO 86.6	WASH. 56.9	CALIF. 22.8	OREG. 22.7	MAINE 21.4	WISC. 21.4	N.D. 20.6	COLO. 19.2	MINN. 15.5	MICH. 15.1	21 1.8

1/ INCLUDES WILD HAY.

LIVESTOCK ON HAND - JANUARY 1, 1985

ITEM	UNIT	1	2	3	4	5	6	7	8	9	10	S.D. Rank
ALL CATTLE AND CALVES	000 HEAD	TEXAS 14,100	NEBR. 6,100	KANS. 5,860	IOWA 5,600	OKLA. 5,300	CALIF. 4,960	MO. 4,850	WISC. 4,440	S.D. 4,160	MINN. 3,550	9 4,160
BEEF COWS THAT HAVE CALVED	000 HEAD	TEXAS 5,586	MO. 2,000	OKLA. 1,993	NEBR. 1,808	S.D. 1,627	MONT. 1,513	KANS. 1,512	IOWA 1,305	FLA. 1,161	TENN. 1,050	5 1,627
CATTLE ON FEED	000 HEAD	TEXAS 2,310	NEBR. 1,880	KANS. 1,530	COLO. 1,000	IOWA 880	CALIF. 598	ILL. 540	ARIZ. 419	MINN. 370	S.D. 355	10 355
ALL SHEEP AND LAMBS	000 HEAD	TEXAS 1,810	CALIF. 1,065	WYO. 860	COLO. 690	S.D. 639	N.M. 538	UTAH 515	MONT. 515	OREG. 430	IOWA 360	5 639
ALL HOGS AND PIGS DEC. 1, 1984	000 HEAD	IOWA 14,200	ILL. 5,400	MINN. 4,300	IND. 4,300	NEBR. 3,700	MO. 3,450	N.C. 2,300	OHIO 1,970	S.D. 1,600	KANS. 1,600	9-10 1,600
CALF CROP - 1984	000 HEAD	TEXAS 5,050	MO. 2,200	WISC. 2,020	OKLA. 2,000	S.D. 1,800	NEBR. 1,800	CALIF. 1,740	IOWA 1,640	MONT. 1,610	KANS. 1,575	5-6 1,800

The control of coyote, fox and beaver account for about 72% of our program expenditures (see table 2). Control of these three species is usually handled directly by our Animal Damage Control staff. The nature of these animals' habits and the serious problems they cause farmers and ranchers require us to utilize our professional staff in order to bring about a quick solution to the problem. A large proportion of what we consider nuisance animal problems are handled by an extension approach. These problems are caused by animals such as raccoon, skunk, mink and badger. With the exception of skunk rabies, the nature of these types of complaints are not considered as serious. Agricultural or property losses are usually not of any large amount. The nature or habits of these types of animals are such that with some minor instruction and minimal assistance, landowners can usually solve the problems themselves.

Table 2.--Breakdown of program activity and expenditure levels for FY '86.

Species	Number of Complaints	Animals Taken
Coyote	729	2,750
Beaver	245	551
Fox	68	624
Badger	29	39
Raccoon	52	163
Skunk	84	76
TOTAL	1,226	4,203

EXPENDITURE/ACTIVITY

Wildlife	Residential/Industrial	Livestock
$13,789	$7,870	$453,546
Ag. Crops	Forest/Range	Health/Safety
$197,103	$59,123	$10,989

The state supervised Animal Damage Control Program receives funding from three sources. In 1983 the state legislature passed a law which established two sources of state revenue. A livestock census for each county in the state is taken every four years. Based on this census, each county appropriates, from its general fund, a sum equal to 4 cents on each head of cattle and 12 cents on each head of sheep within that county. This is deposited semiannually (June, November) into an Animal Damage Control fund. This is matched equally dollar for dollar by the Department of Game, Fish and Parks. The department's contributions are made from wildlife funds generated through the sale of hunting licenses. The third source of revenue is contributed by the U.S. Department of Agriculture, APHIS ADC. In 1976, Game, Fish and Parks entered into a cooperative agreement with U.S. Fish and Wildlife Service. In this agreement Game, Fish and Parks would supervise the Animal Damage Control Program within the framework of federal guidelines. The service would provide for 60% of the program costs up to a maximum of three hundred thousand dollars ($300,000). On December 19, 1985 the federal Animal Damage Control duties were transferred from the Department of Interior, U.S. Fish and Wildlife Service to the U.S. Department of Agriculture, Animal Plant Health Inspection Service. The agreement was renegotiated with APHIS in 1986 and we continue operations under this current agreement.

This past fiscal year (July 1, 1985 - June 30, 1986), revenue sources were as follows; county general funds, $247,000, wildlife funds $247,000 and federal funds $300,000. Our current funding structure allows us to provide services to every tax paying citizen in South Dakota. Each taxpayer and each sportsman who purchases a hunting license has a part in supporting the state Animal Damage Control program. We feel this funding arrangement is not only unique but probably the most appropriately distributed of any Animal Damage Control program currently conducted.

On July 1, 1986, we began to computerize all field reports. This is the first step in the development of a cost accountability program for each county within the state. We currently have the capability to provide information, within minutes, as to man-hours spent, agriculture resource loss, species causing the loss, landowners name and dates of service provided for each county or trapper district. This information, when fully developed, will be essential in justification of continued county participation in funding the program.

Sheep growers have organized themselves in an effort to assist in the state's predator control program. They have formed eight predator control districts. Seven of these districts are west of the Missouri River and one east river. They have set an assessment on sheep ranging from 5 cents to 25 cents per head. Funds collected from this assessment are used to supplement the program in several ways. Private aerial hunters are hired to hunt fox and coyotes in problem areas. Special types of equipment are purchased for state extension trappers to use in their programs. During denning season private trappers are often hired by the districts to assist in denning operations. All funds collected through the assessed surtax are under the control of the district board of directors to be spent within the district in which they were collected.

Big game animals such as elk and deer can cause extensive damage to livestock feed supplies during a long harsh winter. Once snow covers range forage, these animals will bunch and move in on hay stacks and corn piles. Much of the hay supply is spoiled by deer defecating and urinating on the feed. When situations such as this occur, Game, Fish and Parks conservation officers respond by providing feed for the deer or elk, materials for fencing livestock feed supplies or livestock feed to short stop these animals.

U.S. Department of Agriculture, APHIS ADC has a very important role in the State Animal Damage Control Program. In addition to providing cooperative funding for the Game, Fish and Parks state program, this agency is responsible for controlling damage caused by migratory birds and waterfowl. The agency oversees all prairie dog control operations that are conducted on the various Indian reservations, including coordination of ferret surveys, monitoring bait quality and application rates and making various procedural recommendations to improve control success. Technical assistance is provided other state and federal agencies in resolving animal damage problems.

The South Dakota Department of Agriculture has a variety of responsibilities that contribute to the Animal Damage Control Program. The agency has the regulatory authority over the registration, distribution and use of restricted use pesticides. The department coordinates the activities of all county weed and pest boards and is the state enforcement agency for all weed and pest control laws. Another function of the State Agriculture Department is the operation of the state bait plant. This facility formulates and distributes a variety of toxic grain baits used in controlling rodent populations within the

state. To provide for the availability of good quality bait at a competitive price is the goal of this facility. Approximately 1,250,000 pounds of bait has been formulated and distributed from this plant between 1980 and 1986.

The secretary of Agriculture and another designee from that agency and the secretary of Game, Fish and Parks and his designee form an Animal Damage Control Review Committee. Their responsibility is to establish goals and program priorities for the Animal Damage Control Section.

The U.S. Forest Service manages a major portion of public use land in South Dakota. The Nebraska National Forest unit manages most of the forest lands outside of the Black Hills National Forest. These lands are managed for multiple use, however, livestock grazing is the primary use. Regulated grazing is allowed under a permit system. In the mid 1970's prairie dog populations began to erupt on some of the Nebraska National Forest lands. The prairie dog population was beginning to destroy grasses necessary for livestock grazing. This enlarging prairie dog population soon spread to adjoining private land. The decision to address the problem was made in late 1977 and early 1978. A state law was passed during the 1978 legislative session which made Game, Fish and Parks responsible for controlling the prairie dogs on private land adjacent to public land. This addressed the encroachment problem of prairie dogs coming off adjoining Forest Service land. A joint control program was initiated by the Forest Service and Game, Fish and Parks Animal Damage Control Unit in 1978. By the end of the control season in the fall of 1983, the prairie dog problem had been reduced to a maintenance level. In all 42,340 acres of forest land and 14,250 acres of private land had been controlled. Because of excellent coordination the program was not only successful but much less costly than it may have been. Coordination assured complete control and eliminated the possibility of continued prairie dog migration from uncontrolled areas to areas having been treated.

During this same time, a massive program was being planned and initiated on the Pine Ridge Indian Reservation. Preliminary estimates indicated that prairie dogs covered an area of more than 300,000 acres on the reservation. It was by far the most serious problem in the state. Since the reservation bordered a large portion of the area that was being controlled by the Forest Service and Game, Fish and Parks, it became apparent that coordination with the Pine Ridge program was necessary. Annual coordination meetings were established at which time plans for the upcoming year were formulated. Participants of these meetings included, Bureau of Indian Affairs, Pine Ridge Reservation, Rosebud Reservation, Cheyenne River Reservation, U.S. Department of Agriculture, U.S. Forest Service, Bureau of Land Management, South Dakota Department of Agriculture and Department of Game, Fish and Parks.

In 1983, Pine Ridge embarked on what was called "The Five Year Plan". This plan called for the complete control of prairie dogs on the reservation and implementation of range renovation measures. The program was a massive undertaking but turned out to be a tremendous success. With the treatment of about 11,000 acres in 1987, along with some mop-up efforts, the prairie dogs on the reservation should be at a management level. Range renovation is underway through such measures as deferred grazing, fencing and livestock water distribution. Grazing land that produced nothing more than cactus just a few years ago is now responding with grass. With renewed emphasis on range management this land will once again produce as it once did.

What we have learned in South Dakota is that coordination and cooperation between governmental units, professional agricultural and wildlife organizations and landowners results in a very successful Animal Damage Control program. However, this success doesn't come easy. It takes a lot of time and effort from all cooperators to cause a program like this to enjoy the staunch support of the beneficiaries. This support from these people, even in the face of adversity, makes the effort worthwhile and makes you feel good about yourself and the people you work with.

ADC in the U.S. Department of Agriculture[1]

Gerald J. Fichtner[2]

ADC transferred to the U.S. Department of Agriculture by Public Law 99-190. Parameters of ADC in USDA are that the program is biologically sound, environmentally acceptable, and economically feasible. Major program components are cooperative operational control, education and information, and research. The National Animal Damage Control Advisory Committee is being formed. The American Society for Testing and Materials is helping on research priorities. A line-staff organization has been put in place within the Animal and Plant Health Inspection Service in USDA.

INTRODUCTION

I'm most pleased to join you today to talk about national perspectives on animal damage control in the U.S. Department of Agriculture. As you know, USDA has only recently acquired the ADC program from the Interior Department. But the program had its beginnings at USDA, and we're very glad to have it back after a 46-year absence. ADC is alive and doing very well under the auspices of USDA's Animal and Plant Health Inspection Service. I welcome this challenge to work with you and our cooperators in animal damage control.

I've spent most of my working career in USDA's Animal Health Programs--first with Agricultural Research Service and then with APHIS after it came into being in 1971. APHIS has its roots in the old Bureau of Animal Industry created in 1884 to combat serious animal disease outbreaks.

It was also in the 1880's that USDA first began studies to control agricultural losses caused by rodents, birds and other wildlife. The ADC program, as we know it, came into being with passage of the 1931 Animal Damage Control Act. Eight years later, it was transferred to Interior as part of a general realignment of agency functions during Franklin Roosevelt's era.

In recent years, however, it became increasingly important to the agricultural community that the ADC program's mission should be directed towards protecting U.S. Agriculture, and it was returned to USDA by Public Law 99-190 in December 1985. By April 1986, transfer of all personnel and resources had been effectively completed.

Few would deny that depredating animals--such as blackbirds, rodents and coyotes--still present a serious threat to agricultural production. Figures developed through various studies show predators still kill significant numbers of lambs born in the United States. Blackbirds, starlings and migratory waterfowl are causing increasingly significant damage to crops such as corn, small grains, rice, sunflowers, fruits and vegetables. Rodents also damage crops and pastures and chew up huge volumes of stored grains.

ADC is already fitting in very well with the overall APHIS mission of "protecting American agriculture." It has become a third major program area of the Agency, the other two being Plant Protection and Quarantine and Veterinary Services.

SOME GUIDING PRINCIPLES OF APHIS

All three major programs of APHIS are dedicated to protecting crops and livestock from pests or disease, and all three involve cooperative working relationships and cost-sharing with States and the agricultural community.

Incidentally, I'm pleased to report that four Eastern States have entered into cooperative agreements with USDA. This means additional resources coming into the program in those States.

Unlike VS and PPQ programs, ADC is not a regulatory program. It's also different in that it has its own methods development and research facility. This gives APHIS a management role in research it hasn't had before. Except in the

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[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop, Howard Johnson's, Rapid City, S.D., April 28-30, 1987.

[2]Gerald J. Fichtner, Deputy Administrator, Animal Damage Control, APHIS, USDA, Washington, D.C.

area of field trials, Agricultural Research Service handles all such matters for our other programs.

All three APHIS programs are based on sound research and valid scientific criteria. I personally believe that continued research is vital to an effective and efficient ADC program in the future.

Let's turn our attention now to how USDA, APHIS, plans to manage this program. First, be assured that we're determined to implement an ADC program that is both cooperative and beneficial.

When I say "cooperative," I mean cooperative at the State, county, farm community, and individual rancher levels. We inherited more than 700 cooperative agreements from Fish and Wildlife Service. APHIS has no intention of taking over jobs already being well-handled at the State, county, and community levels. Program structures within each State will remain largely intact.

When I say "beneficial," I mean the program provides a direct public service to:

-- raisers of sheep, goats, poultry, hogs, and cattle

-- operators of granaries and feedlots

-- growers of grains, forage, fruit, nuts, flowers, melons and timber.

In other words, our emphasis in the future will be on protecting agriculture. You'll not see us initiating urban ADC programs; but we will cooperative, as appropriate, with ongoing urban efforts that are funded at State or local levels. Such cooperation usually takes the form of technical or advisory assistance.

Of course, we'll always respond to emergencies or situations where public safety is at risk and USDA-ADC expertise is needed to help overcome dangerous situations. And we'll continue to respond, as appropriate, to Federal or State efforts to protect endangered species.

All program efforts, however, must pass the scrutiny of being biologically sound, economically feasible, and environmentally acceptable. Applicable statutes are the National Environmental Policy Act; the Federal Insecticide, Fungicide and Rodenticide Act; and the Endangered Species Act. Also, USDA-APHIS, administers various humane laws as they apply to warm-blooded animals, so we're sensitive to public concerns in that area.

The ACT program under APHIS consists of the following components:

-- a cooperative operational program that's responsive to needs

-- an applied research program that supports the operational program

-- an information/education program based on both APHIS initiatives and field services in cooperation with the Extension Service.

The Extension Service has been involved in ADC since 1914. Its aim is to help landowners and agricultural managers help themselves. Emphasis is on prevention and control--stressing the most practical, safe, effective and humane procedures available. Extension programs are implemented primarily through county extension agents who provide demonstrations and group training for producers. It is anticipated that ADC will become more pro-active in the development and dissemination of training and informational materials structured for use with modern day audio-visual materials.

ORGANIZATION

At the national level, ADC is headed by a Deputy Administrator's office with a small staff in downtown Washington, D.C. Our responsibility is to set program priorities and goals, help in acquiring resources for program implementation, and marshall a coalition of support necessary for program continuation and growth.

The program also has a National Technical Support Staff in nearby Hyattsville, Maryland. This small staff, under a director, has the responsibility of assuring the program's overall technical excellence.

As part of a streamlining effort, APHIS has organized the cooperative operational program under two regional directors. The program used to function under seven regional directors of Interior's Fish and Wildlife Service.

Our Eastern Director, responsible for 31 States, is headquartered in Brentwood, Tennessee. Our Western Director, responsible for 19 States, is headquartered in Denver. Primary responsibility for conduct of field program activities and management of field resources is delegated to the Regional Directors.

There's an ADC director for each State with some of the larger States having a number of district offices. In New England, however, there's one director for three of the small States.

Regional and State offices and other field stations now receive administrative support services from our APHIS Field Servicing Office in Minneapolis. In theory, this allows them to concentrate their energies on the job of program management. Although there are several advantages to this system, a complete review is needed to make resource management at the regional and State levels more effective.

The Western regional headquarters shares facilities with the Denver Wildlife Research Center, now under APHIS. This facility is the hub of most of the ADC applied research pursued in this country and several overseas locations.

The Center's nearly 100 scientists seek practical solutions to field problems:

-- they explore the use of repellents, attractants, surfactants, and biological controls such as reproductive inhibitors

-- they investigate coyote behavior and predator-prey population dynamics

-- they examine toxicants, developing guidelines for their safe use in the natural environment and performing studies needed for EPA registration.

One of their most perplexing projects has to do with finding a safe toxicant for blackbirds that is environmentally safe. But don't expect instant results.

We're now in the process of reassessing our ADC research priorities. You'll see more effort going into applied research. We must put more effective tools into the hands of the operational side of the program.

The ADC Supply Depot at Pocatello, Idaho, continues to formulate and distribute baits, traps, and toxicant supplies needed by the ADC program. The director of this facility reports to the director of the National Technical Support Staff in Hyattsville, Maryland.

SPECIAL PROJECTS

We've begun an internal training program to increase the professional and managerial competence of all ADC personnel in a variety of program activities. Our initial efforts will be concentrating on:

-- technical training

-- executive/managerial and supervisory training

-- techniques to enhance the exchange of knowledge between regions, States, and cooperators and the agricultural community

Recognizing a general need for highly trained staff, our Management Team has recommended an intensive two-year program to train newly recruited employees for eventual supervisory positions.

The first class of 20 highly qualified men and women will begin training under specialized individual development plans. These plans are designed to give each trainee a broad range of technical and supervisory training in both the Eastern and Western Regions, according to the trainee's prior professional background and needs.

INFORMATION

We also plan to design, develop and implement a nationwide automated data system that'll greatly expand our data base related to ADC. Specific needs are now being assessed before proceeding with the purchase and modification of computer software to meet our unique requirements. Once in place, this computer system should become an invaluable tool for making management decisions and for the rapid dissemination of information. The system will be designed to interface with other important data bases within USDA.

SPECIAL GROUPS

To assist in program management, a Management Team for ADC has been developed. Members include the Deputy Administrator, Associate and Assistant Deputy Administrators, the two Regional Directors, and Directors of the Denver Wildlife Research Center and the National Technical Support Staff.

This Team takes a direct hand in recommending policy and direction for ADC operations, research, education, and related matters and, hopefully, become stakeholders in program and resource management policy.

At the Department level, an Intra-departmental Policy Committee has been formed. Its members include top officials of Agricultural Research Service, Cooperative State Research Service, Economic Research Service, Extension Service, Forest Service, and APHIS. Our APHIS Administrator is Chairman. This Committee helps delimit the roles of various USDA agencies in ADC, and it influences the direction of ADC's cooperative operational programs and research.

Recently, the USDA intra-agency committee asked the American Society for Testing and Materials to assist in reassessing the program's research priorities. ASTM has agreed to review past, present, and proposed ADC-related research. It will prepare a summary review and provide us with recommendations on a continuing basis. To accomplish this, ASTM has established an ADC Task Force Group. The Group will have broad representation from the scientific community.

Of great importance is the recent approval to establish a Secretary's Advisory Committee on ADC with representatives from environmental groups, agricultural groups, and the academic-scientific community. Now that the preliminaries are completed, we can begin selecting about 20 such members. With one exception, members will come from private or non-Federal organizations. Congress has indicated that Fish and Wildlife Service should also be represented. This group will advise the Secretary of Agriculture on ADC operational and research questions and--more importantly--serve as a public forum.

There will be no mysteries about what we're doing or how we're going about it.

CONCLUSION

In summary, USDA has inherited an ADC program which has several good things going, including a clear mission, personnel who are competent and have high morale and good cooperative relationships with Federal, State and industry. We're taking steps to enhance:

1. a high level of professional performance,
2. increase information, and
3. seek outside expertise.

In a few years, I hope that you and the public you serve will have every reason to be proud of the legacy you built as part of APHIS's role of "protecting American agriculture."

Current and Future Status of Rodenticides and Predacides[1]

Steve Palmateer[2]

I appreciate the opportunity to convey the current and future status of rodenticides and predacides at this workshop. According to the computer, the Agency has 2,888 products classified as vertebrate control agents. The Federal Insecticide, Fungicide, and Rodenticide Act tends to clump all vertebrate pesticides as rodenticides. This includes fish toxicants such as TFM; bird toxicants and repellents such as Starlicide and Avitrol; dog repellents such as lemongrass oil; bat toxicants and repellents such as naphthalene; commensal rodent toxicants such as warfarin, diphacinone, bromadiolone, brodifacoum, and red squill; field use rodenticides for many species (e.g., prairie dogs, ground squirrels) using pesticides such as 1080, strychnine, zinc phosphide; predacides such as 1080 and sodium cyanide; and animal browsing repellents such as thiram and putrescent whole egg solids.

I will not attempt to list all the currently registered vertebrate toxicants as Ray Matheny accomplished this task in 1980 at the Ninth Vertebrate Pest Conference in Fresno, California. The only major changes to Ray Matheny's list are the deletion of DDT as a bat toxicant (voluntarily cancelled by the Centers for Disease Control in March 1987), and the addition of Bromathalin, alphachlorohydrin, bromadiolone, brodifacoum and cholecalciferol.

The status of Fumarin is uncertain at this time as the only manufacturer of technical Fumarin has declined to support the registration with the necessary generic data. Therefore, the generic data requirements will be the responsibility of the registrants of end-use products.

Approximately 200 of the Warfarin/Prolin registrants successfully satisfied the data call-in issued in October of 1981. At this writing there are two registrants who have satisfied the generic data requirements for Warfarin, and six more companies have repackaged these products.

In the next fiscal year there are no Registration Standards scheduled primarily for vertebrate pesticides. However, there are two Standards that have been issued recently that have some vertebrate claims on the label (Mesurol and Lindane).

PREDACIDES

At the present time the Agency has only one active experimental use permit (EUP) for a predacide. This is a 1080-treated single dose bait for the control of the Arctic Fox on Kiska Island, Alaska. The EUP allows for up to 50,000 1080-treated meat baits to be broadcast on the outer perimeter of the 69,000 acre island during the winter, when the fox is stressed for food. The artificially introduced fox is a predator of the Aleutian Canada Goose and has completely eradicated all of the geese from the Island. The Department of the Interior felt it could not reintroduce the goose until the fox was completely eliminated from the Island. The experiment apparently was a success, as during the January 1987 census there were no foxes detected. The EUP allowed for an additional 50,000 1080 baits to be applied if any foxes had been detected. When the EUP was proposed by Interior it was their expressed intention to use the information gleaned from this experiment to support a section 3 application for registration of a 1080 bait to control the Arctic fox on more than 30 other islands in the Aleutian chain.

The EUP for single dose 1080 baits for coyotes that prey on livestock has expired. A final report is due in May 1987.

The agency has three pending "me-too" registration applications for the Livestock Protection Collar (Montana Department of Livestock, Wyoming Department of Agriculture, and Rancher's Supply of Alpine, Texas). The Wyoming and Montana applications are pending completion of final administrative details. Rancher's Supply requires revised labels and a monitoring plan.

The administrative Law Judge has not issued a decision on the use of the M-44 on National Wildlife Refuges to protect endangered species. Since there was a restriction placed by an Administrative Law Judge against the use of M-44's on National Wildlife Refuges, a Subpart D hearing was required to modify that order. When the Judge makes a Recommended Decision, the final decision has to be made by the Administrator. Two State Conservation Departments have also expressed interest in using the M-44 to control coyotes that prey on game species. This use will also require a Subpart D hearing.

The Agency has pending applications for registration from the Montana Department of Livestock and the Wyoming Department of Agriculture for labels for strychnine-treated eggs to control rabid skunks. Since this is a cancelled use for strychnine, a Subpart D hearing was required.

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[1] Paper presented at the 8th Great Plains Damage Control Workshop. (Rapid City, SD, April 28-30, 1987).

[2] Steve Palmateer is a Biologist, Environmental Protection Agency, Washington, DC.

Before the Administrator will reconsider a cancellation order he must determine that (1) the applicant has submitted substantial new evidence that may materially affect the cancellation order which was not available to the Administrator at the time of cancellation, and (2) such evidence could not, through the exercise of due diligence, have been discovered by the parties to the cancellation or suspension proceeding prior to the issuance of the final order. The Administrator determined that Wyoming and Montana did submit substantial new evidence and hearings were held in Billings, Montana and Washington, DC. A decision has not yet been reached in that case.

Montana and Wyoming have also committed themselves to supply toxicology and wildlife safety data to the Agency to support their applications for registration.

FIELD USE RODENTICIDES

It is my perception that the people attending this workshop are very interested in the data call-ins on zinc phosphide, 1080, and strychnine, and I will quickly outline the status of these pesticides.

In June 1982, the Agency issued the Zinc Phosphide Registration Standard which also included a data call-in. In September 1984, the Agency suspended most of the section 3 registrations, including all those with prairie dog claims, for failure to satisfy the data requirements. It is important to note that at this time the Agency had suspended the use of strychnine for prairie dog control. Therefore, only Colorado had a vertebrate pesticide (1080) for prairie dog control. Through the administrative hearing process, the Agency lifted the zinc phosphide suspensions of products with "prairie dog use" only claims. Since that time many of the zinc phosphide end-use products have successfully completed all the data requirements and have been reregistered.

However, none of the technical zinc phosphide manufacturers have satisfied all the data requirements and are subject to suspension. The main problem has been the whole body residue test and acute toxicity to freshwater fish.

1080

In November 1985, the Agency issued a call-in of data for 1080 for all intrastate products and the one Oregon special local need product. California responded with 36 applications for registration and Colorado with two. The county of Klamath Falls was not required to submit a section 3 application but was required to commit to supplying the data. Klamath Falls County did agree to supply the data and submitted revised labels. Nevada declined to respond, and its intrastate products were administratively withdrawn.

In December 1986, both California and Colorado submitted data to support their pending registrations. At this writing the data are being reviewed, and a decision is pending completion of this data review.

STRYCHNINE

In October 1983, the agency issued notice that it was going to cancel many uses of strychnine, including _Microtus_ and all species of prairie dogs. This notice (FR Vol. 48, No. 203) was mailed to all strychnine registrants and required many label modifications and served notice that ground squirrel data would be called in.

Several registrants and other persons felt they were adversely affected by the cancellation notice and requested a hearing. After a long protracted negotiated settlement, the Agency revised the prairie dog and _Microtus_ cancellation. A notice of the revised cancellation notice and required label modifications was published in the Federal Register on March 4, 1987 (FR Vol. 52, No. 42). The Agency will mail a copy of this notice to all strychnine registrants in the near future. At this time the Agency is being sued by the Defenders of Wildlife, et al., to cancel all uses of strychnine. The major reason being offered for the lawsuit is that the Agency is not carefully following the mandates of the Endangered Species Act.

The Agency called in the strychnine wildlife safety-efficacy data in August 1984 and issued a general data call-in for all strychnine products in October 1986. In addition to requiring the general product chemistry, residue chemistry, environmental fate, and toxicology, the Agency requested considerable efficacy and wildlife safety data. It is hoped that much of the strychnine data being generated to support the registration of the pending applications for strychnine-treated eggs to control rabid skunks will be useful for some of the generic strychnine data. This is also dependent on whether the owners of these data will allow its use by other registrants.

As for the future, there are several new chemicals pending with the Agency which are slated for rodent control. While most of these new rodenticides are being proposed for commensal rodents and other vertebrate pests for use in and around homes, it is expected that they will eventually be used for field rodents. I cannot elaborate on the exact nature of these new chemicals as they do not have patents at this time and the manufacturers are entitled to confidentiality.

Demography and Population Dynamics of Prairie Dogs[1]

John L. Hoogland[2], Diane K. Angell[3], James G. Daley[4], and Matthew C. Radcliffe[4]

Abstract.--For the last 14 years, we have been studying the sociobiology, demography, and population dynamics of black-tailed prairie dogs (Cynomys ludovicianus) in Wind Cave National Park, South Dakota. Our study colony covers 6.6 hectares (16 acres) and has not expanded during the period of research; in late spring of each year the colony contains a mean ± SD of 133 ± 29 adults and yearlings and 81 ± 33 juveniles. We have discovered four surprising aspects of the demography and populations dynamics of prairie dogs. (1) Mortality during the first year is approximately 50% for both sexes. Those males that survive the first year can live as long as 5 years, and females that survive the first year can live as long as 7 years. (2) Litter size ranges from 1 to 6, the mean ± SD is 3.05 ± 1.08, and the mode is 3. (3) Although individuals of both sexes usually defer first breeding until the second year, 9% of females and 3% of males first produce offspring as yearlings. (4) Infanticide is the major source of juvenile mortality, accounting for the partial or total demise of 51% of all litters born. In the most common type of infanticide, lactating females kill the unweaned offspring of their sisters and daughters.

INTRODUCTION

Black-tailed prairie dogs (Cynomys ludovicianus) are large (600-1200 grams), diurnal, colonial, harem-polygynous rodents of the squirrel family (Sciuridae) (King 1955; Koford 1958; Smith 1958; Tileston and Lechleitner 1966; Foltz and Hoogland 1981). At Wind Cave National Park, Hot Springs, South Dakota, prairie dogs breed in February and March, and juveniles first emerge from their natal burrows in May and June (King 1955; Hoogland and Foltz 1982). Colony residents live in contiguous family groups called coteries (King 1955), which typically contain one adult (≥ 2 years old) male, 3-4 adult females, and several yearling and juvenile offspring. Coterie members restrict all foraging and other activities to a clearly defined, vigorously defended coterie territory. Litter size, juvenile growth rate, survivorship during the first year, age of first reproduction, and pregnancy rate all seem to be affected by the availability of food (Garrett et al. 1982). Estrous females usually copulate exclusively with the adult male in the home coterie (Hoogland and Foltz 1982), and inbreeding is rare (Hoogland 1982a; Foltz and Hoogland 1983). Females within a colony synchronize their breeding, and synchronization within coteries is also evident (Hoogland 1981a). The mean ± SD gestation period for prairie dogs is 34.8 ± 0.7 days (N = 32; range = 34-37), and the mean ± SD time between parturition and the first emergence of weaned juveniles is 43.4 ± 3.5 days (N = 17; range = 38-50) (Hoogland 1985a).

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[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop [Rapid City, South Dakota, April 28-30, 1987].

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Disadvantages of coloniality for individual prairie dogs include increased aggression and increased ectoparasitism by fleas and lice (Hoogland 1979a). To offset these costs, there may be only one benefit of prairie dog coloniality: increased protection from predators such as coyotes (Canis latrans), badgers (Taxidea taxus), bobcats (Lynx rufus), golden eagles (Aquila chrysaetos), prairie falcons (Falco mexicanus), and various buteo hawks (Buteo spp.) (King 1955; Hoogland 1981a). Prairie dogs in large colonies not only detect predators more quickly than do dogs in smaller colonies, but also spend less time scanning for predators (Hoogland 1979b, 1981a). The dense coloniality of prairie dogs which has evolved in response to most predators has evidently left the dogs especially vulnerable to another predator: the black-footed ferret (Mustela nigripes) (Hoogland 1981a, 1982b). Ferrets do not prey heavily on prairie dogs now since the ferrets are so rare, but may have been important in regulating prairie dog numbers for most of the prairie dogs' evolutionary history (Hoogland 1982b).

Nepotism, the preferential treatment of genetic relatives (Alexander 1974; Sherman 1980), is pronounced among prairie dogs. For example, individuals are less likely to fight with, and more likely to interact amicably with, kin than with nonkin (Hoogland 1981b; Hoogland 1986). Further, prairie dogs with living kin within earshot are more likely to give an alarm call in response to a predator than are dogs without such kin (Hoogland 1983a).

Here we report our findings that are relevant to the demography and population dynamics of prairie dogs.

METHODS

Our study colony, inhabited for at least the last 35 years and possibly much longer, is approximately 500 meters x 130 meters (6.6 hectares). Most of this colony is surrounded by trees, but there is room for potential expansion at the south end. The colony is gridded into 15.2 m x 15.2 m squares with garden stakes, and burrows are marked with Ritchey Cattle Eartags mounted on clothesline wire (Hoogland 1977). The nearest other colony to the study colony is approximately 0.7 kilometers away.

For permanent identification, prairie dogs are marked in the ear with numbered National Band and Tag Fingerling Tags (Hoogland 1979a). Each eartag usually remains with the dog until its death, but tags are sometimes lost during vicious fights. For this reason, one numbered tag is placed in each ear; since 1975, only five dogs, including all four offspring from one litter, have lost both eartags. Using prairie dogs of known age for comparison, we have recently devised a method for placing individual dogs of unknown age into one of three age classes (Hoogland and Hutter 1987). Through eartagging, observation, and an electrophoretic analysis of blood samples, maternal, sibling, and putative paternal genetic relationships have been determined for all young weaned at the study colony since 1975 (968 young from 317 litters) (Foltz and Hoogland 1981; Hoogland and Foltz 1982; Hoogland 1986).

For visual identification from a distance, we use Nyanzol-D fur dye from J. Belmar Inc (King 1955; Hoogland 1979a). Males are marked with numbers under 50, and females are marked either with numbers above 50 or with gross markers such as stripes and blotches. Dogs marked with Nyanzol-D can be identified with binoculars from distances over 300 meters.

Observations are made from three 5-meter high observation towers positioned at the periphery of the study colony. From before the first copulation in mid-February until the last juvenile has been eartagged and colormarked in June, all three towers are manned from early in the morning before any dogs emerge until late in the afternoon when all dogs have immerged for the night.

RESULTS

Variation in population size.--The number of adults and yearlings in April at the study colony has ranged from a low of 92 in 1985 to a high of 216 in 1975, with a mean $\pm$ SD of 132.5 $\pm$ 29.3. The number of weaned juveniles has ranged from a low of 4 in 1975 to a high of 133 in 1986, with a mean $\pm$ SD of 80.7 $\pm$ 33.0. As expected, the number of weaned juveniles seems to vary inversely with the number of adults and yearlings. In other words, prairie dogs at the study colony typically produce more offspring when colony size (the number of adults and yearlings) is low, and fewer offspring when colony size is high (Hoogland, in preparation). Within a coterie, the number of weaned offspring also varies inversely with the number of adults and yearlings (Hoogland 1981b).

Variation in physical area of colony.--Even though the number of prairie dogs foraging aboveground at the study colony has ranged from 92 in April of 1985 to 252 in May of 1981, the physical area occupied by the dogs has remained EXACTLY THE SAME for fourteen consecutive years. Further, despite dramatic fluctuations in the number of dogs within a coterie, most of the coterie territories at the study colony have remained exactly the same for fourteen consecutive years. Increases in the size of the home coterie territory usually occur only after expansion into an adjacent coterie territory in which all the females have disappeared.

Variation in number of burrow entrances.--When we mapped the study colony in May of 1975, there were 1,591 burrow entrances (Hoogland 1977). While the prairie dogs typically excavate several new burrow systems each year, others disappear from lack of use. The result is that the number of burrow entrances has remained remarkably constant, varying by fewer than 10 entrances from one year to the next (Hoogland, unpublished).

Longevity.--For males at the study colony, survivorship during the first year has ranged from 13/36 = 36% in 1984 to 34/43 = 79% in 1980, with a mean ± SD of 51% ± 16%. Males that survive the first year commonly live to be 3 or 4. Only 9 males have lived as long as 5 years.

For females at the study colony, survivorship during the first year has ranged from 13/41 = 32% in 1978 to 27/39 = 69% in 1980, with a mean ± SD of 56% ± 13%. Females that survive the first year commonly live to be 4, 5, or even 6. Only 12 females have lived as long as 7 years.

Age of first reproduction.--In general, individuals of both sexes do not first reproduce until February-March of the second year (King 1955; Hoogland and Foltz 1982). Although approximately 40% of females first copulate as yearlings, only 20 /213 = 9% of yearling females have successfully weaned a litter. Many females do not first wean a litter until 3 or 4 years old. Mainly because of infanticide (see below), the mean ± SD percentage of adult females that weans a litter each year is only 47% ± 14% (range = 30% in 1976 to 73% in 1986). Only 7/216 = 3% of yearling males have successfully sired offspring.

Litter size.--Litter size at first juvenile emergence among prairie dogs at the study colony ranges from 1 to 6, with a mean ± SD of 3.05 ± 1.08 (N = 311 litters); we have no information about litter size at birth. The most common litter sizes at first juvenile emergence are 2 (19%), 3 (38%), and 4 (26%). As predicted from ecological theory (Williams 1957; Sherman and Morton 1984), the relationship between female age and litter size at first juvenile emergence is curvilinear: litter sizes of 3- and 4-year old females are larger than litter sizes of younger and older females (Hoogland, in preparation). The relationship between male reproductive success and age may also be curvilinear.

Variation in sex ratio at weaning.--For all young weaned at the study colony each year, the percent of males has varied from 31/74 = 42% in 1985 to 55/93 = 59% in 1983, with a mean + SD of 53% + 6%. We have no information about the sex ratio at birth.

Dispersal and immigration.--In general, prairie dog females at our study colony remain in the natal coterie territory for their entire lifetimes (Hoogland 1982a; see also Garrett 1982). Those rare females that do disperse usually leave the study colony entirely. Only 3 females have successfully transferred from the natal coterie into another coterie within the study colony. Since 1975, only 5 females have immigrated into the study colony from somewhere on the outside and then weaned offspring. None of these females was recruited into an established coterie territory. Three of these immigrants lived at the periphery of the study colony, and the other two evicted females from established coterie territories and then moved into these vacated territories.

Yearling males at the study colony typically disperse from the natal coterie territory approximately 12-14 months after weaning (Hoogland 1982a; see also Garrett 1982). These young males sometimes disperse to other coteries within the study colony, but other times leave the study colony entirely in search of another colony. Occasionally males remain in the natal coterie territory for a second year: almost invariably, these males delay sexual maturity until the third year. Although the peak of dispersal by yearling males occurs in May, June and July, a second peak occurs in February, just before the onset of the breeding season. Older males also disperse after one or two years in the same coterie, probably to avoid inbreeding with their daughters (Hoogland 1982a). Whereas younger males disperse both intra- and inter- colonially, older males seem to restrict almost all of their movements to the study colony, and most of these older males disperse to adjacent coteries. Since 1975, only 14 males have immigrated into the study colony from somewhere on the outside and successfully sired offspring there.

Infanticide.--Infanticide, the killing of juvenile conspecifics (Sherman 1981; Hausfater and Hrdy 1984), is the major source of preweaning and postweaning juvenile mortality at the study colony, accounting for the total or partial demise of 51% of all litters born. Infanticide occurs in four different contexts (Hoogland 1985a, in preparation), as summarized below.

In Type I infanticide, female immigrants from somehere on the outside move into an established coterie territory in late spring or early summer, evict the resident females there, and then kill the recently weaned offspring. This is the rarest type of infanticide, mainly because female immigrants are so rare, and accounts for the elimination of 1% of all litters born.

In Type II infanticide, females abandon their offspring shortly after parturition and allow other coterie members to kill and cannibalize them. The details and possible reasons are poorly understood for Type II infanticide, which accounts for the elimination of 13% of all litters born.

As noted above, most dispersals by young males occur in May and June, just before or just after the weaning of juveniles. When a yearling male is successful in entering a new coterie, all the unweaned or weaned juveniles typically disappear within a few days. Male invaders presumably kill the juveniles that disappear (Type III infanticide): maimed carcasses were found aboveground after six invasions, and actual killings were observed twice. Type III infanticide accounts for the total or partial elimination of 7% of all litters born.

Type IV infanticide is the most extraordinary, since it involves the killing by lactating females of the offspring of close kin (mother, daughter, sister, aunt, niece, etc.) within the home coterie. Type IV infanticide is also the most common, accounting for the total or partial elimination of 30% of all litters born. Lactating females may kill

and cannibalize nondescendant juvenile kin in order to obtain sustenance necessary for the weaning of their own litters, or they may kill to remove future competitors from themselves and their offspring. Type IV and other types of infanticide observed at the study colony do not result merely from possible overcrowding, since infanticides were also observed at two other colonies at Wind Cave, both of which were young and expanding.

DISCUSSION

Here we have summarized those findings of our study that pertain to the demography and population dynamics of black-tailed prairie dogs at Wind Cave National Park, South Dakota. These findings have direct relevance to those situations in which management and control of prairie dogs might be considered necessary. To further investigate management of prairie dogs, one of us (Radcliffe) has initiated research to determine how quickly prairie dog colonies return to initial size after an artificial reduction of 90%. Another of us (Daley) has begun to examine the effects of colony size and artificial reduction on genetic variation within and between prairie dog colonies. All of us are continuing to investigate infanticide: if we can better understand why prairie dogs regularly kill 51% of all offspring born and those conditions which encourage such infanticide, then perhaps it will be possible to devise effective methods of management which capitalize on infanticide and which do not require shooting or poisoning.

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Control of Ecosystem Processes by Prairie Dogs and Other Grassland Herbivores[1]

James K. Detling[2] and April D. Whicker[3]

Abstract.--Black-tailed prairie dogs in the mixed-grass prairie at Wind Cave National Park, South Dakota, create habitat patches characterized by altered species composition, lower standing crops of plants, but higher forage quality. Native wildlife species such as bison, pronghorn, and elk preferentially feed on these prairie dog colonies and likely derive nutritional benefits from doing so.

INTRODUCTION

The impact of animals on ecosystem functioning received limited attention in older ecological literature. However, more recently, plant-animal interactions, particularly herbivory, have received widespread attention (Harper 1977, Crawley 1983, Strong et al. 1984). Herbivores in most ecosystems remove a very small amount (<10%) of plant production (Chew 1974), but in grasslands, estimates of 30 to 50% removal of aboveground net primary production are common (Wiegert and Evans 1967, Lacey and Van Poollen 1981, McNaughton 1985). Although amount of plant production removal is an indication of the effect that animals may have, it does not fully explain the complex interactions that herbivores have with their environment. Herbivores can influence rates of primary production, nutrient cycling, structural change, and decomposition which, in turn, may affect behavior and nutritional ecology of other animals. Our research focuses on prairie dogs as native herbivores in grassland ecosystems, and also addresses some fundamental questions regarding herbivory.

Prairie dogs are often viewed as pests in western rangelands. As a result, much prairie dog research has focused on their potential as competitors with cattle (Koford 1958, Hansen and Gold 1977, O'Meilia et al. 1982, Collins et al. 1984, Uresk 1985). Such studies have described prairie dog diets and have indicated how their activities change composition of plant communities. Although there have been comprehensive studies on prairie dog behavior and ecology (Clark 1986), their role as herbivores in natural ecosystems has received little attention.

Our research has been conducted on black-tailed prairie dogs (Cynomys ludovicianus) in the mixed-grass prairie at Wind Cave National Park, South Dakota. We have studied structure and function of plant populations and communities on and off prairie dog colonies, and the influence of prairie dog activity on distribution, behavior, and community composition of such diverse animals as bison and nematodes. We have also measured prairie dog-induced changes in the physical environment. This review summarizes our work in a population, community, and ecosystem context.

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PRAIRIE DOG-PLANT INTERACTIONS

Plant Population Parameters

Morphological and physiological changes often occur in intensively grazed plants. For example, plants grazed by domestic herbivores are often shorter and more prostrate than ungrazed individuals (Hickey 1961). Grazing-induced changes in morphology sometimes quickly disappear following release from grazing (Quinn and Miller 1967), or they may persist, indicating genetic differentiation into distinct ecotypes.

We have investigated differences in populations of western wheatgrass (Agropyron smithii) from an intensively grazed prairie dog colony and from within a large, permanent grazing exclosure (Detling and Painter 1983, Detling et al. 1986). Sod blocks containing western wheatgrass were collected on and off prairie dog colonies and were transplanted to a common greenhouse environment. After nine months, significant morphological differences persisted in plants from the two populations. Plants from the prairie dog colonies had more tillers per plant, fewer leaves per tiller, smaller leaves, higher blade/-sheath ratios and were more prostrate than plants from ungrazed populations. The polymorphism and persistence of these characteristics suggested that these populations were genetically distinct. Grazing has apparently modified the selection pressures and competitive balance that existed in the ungrazed populations, thereby causing a shift in dominance to an ecotype that may be more grazing resistant or, because of its shorter stature, be less intensively grazed.

Several responses of the two ecotypes to simulated grazing were also compared (Detling and Painter 1983). Photosynthetic rates were similar and partial defoliation equally enhanced net photosynthesis in the remaining leaves in the two populations. However, perhaps because of greater photosynthetic rates of leaf blades than sheaths, and greater blade/sheath ratios in the prairie dog colony population, net primary production (relative to undefoliated plants) was essentially unaffected by defoliation in plants from the prairie dog colony, but decreased by 20% following defoliation of exclosure plants. Therefore, although they are less productive, these "grazing morphs" may be more resistant to subsequent grazing than those plants seldom grazed.

Another response to grazing is increased accumulation of silica in leaves of grasses. It has been suggested (McNaughton et al. 1985), based on studies in the African savanna, that this may be a defense against herbivores, because silica decreases digestibility and palatability and promotes tooth wear (Van Soest 1982). We (Brizuela et al. 1986) found silicon concentrations were consistently higher in tillers of A. smithii and Schizachyrium scoparium from heavily grazed prairie dog colonies than from lightly grazed areas. However, repeated defoliation did not increase silicon concentration. Thus higher whole tiller concentrations from colony plants may be explained by higher silicon concentrations in leaf blades compared to sheaths (Cid 1985) and the higher blade/sheath ratios in on- versus off-colony plants (Detling and Painter 1983).

In general, as plants mature their nutritive value declines (Van Soest 1982). However, grazing removes aging leaves and may stimulate growth of new tissue, which usually has a higher nitrogen concentration and greater digestibility than that of an ungrazed plant (McNaughton 1984). Part of our research at Wind Cave involved examination of the effect of prairie dog colonization and grazing on plant nutrient dynamics (Coppock et al. 1983a). A prairie dog colony was divided into three ages, or states of colonization: (a) an older area, colonized more than 25 yr, (b) a young area, occupied 3-8 yr, and (c) a recently (<2 yr) colonized edge. The (d) uncolonized prairie was used as a baseline, control site. During the growing season, live material of six grass species (three cool season species and three warm season species), a composite of forb species, and a dwarf-shrub, Artemesia frigida, were collected monthly in each site and analyzed for nitrogen concentration and digestibility.

In general, shoot nitrogen concentrations were lowest in plants from the uncolonized grassland, and increased with the length of time an area had been occupied. Similar results for western wheatgrass were also observed (Krueger 1986). On an average, cool season grasses had higher nitrogen concentrations throughout the season than did warm season species for each state of colonization. Digestibility of grasses followed a pattern similar to nitrogen concentration: digestibility declined as the season progressed; grasses from the uncolonized area had lower digestibilities than those from the edge or young colony; cool season grasses were more digestible than warm season ones. These

results indicate that prairie dogs have a directional effect on plant nutrition and positively influence forage quality by their grazing.

Plant Community Parameters

When prairie dogs invade an area, they crop the vegetation to a height of a few centimeters and maintain it in that state. This can create microclimatic changes within the canopy and soil. Archer and Detling (1986) observed significant increases in soil temperature and as great or greater soil moisture content on prairie dog colonies as off. These abiotic changes can directly influence such things as rate of microbial activity, nutrient cycling, plant water balance, and plant production. These effects can further change the microhabitat, and thus the plant community. Cause and effect rapidly become obscured, but it is clear that grazing, directly or indirectly, modifies either the competitive balance of plants within the colony or modifies the environment such that some plants are better adapted than others.

Following occupation by prairie dogs, overall canopy height decreases and grasses are replaced by forbs. In one of our research colonies, the mean canopy height decreased 62% in the first two years of colonization, and changed little thereafter (Archer et al. 1987). Change in canopy structure can be achieved in several ways: (1) plants that are clipped repeatedly never reach full growth; (2) genetically determined taller morphs are replaced by grazing tolerant, shorter, prostrate ecotypes of the same species (Detling and Painter 1983); and (3) the plant community changes such that many of the taller species are replaced by shorter species (Koford 1958, Coppock et al. 1983a, Archer et al. 1987).

These same factors may contribute to concomitant decreases in standing crop following colonization. In one site, the greatest peak live standing crop (190 g/m^2) was found in uncolonized prairie, where grasses comprised 85% of the biomass (Coppock et al. 1983a). Similar biomass levels were found in the oldest portion of the colony; however, less than 3% of that was grasses. The grass-dominated young area of the colony only had about one-third the live standing crop as the uncolonized area. However, there was a greater proportion of live material relative to standing dead in the colonized areas compared to the uncolonized prairie. Because prairie dogs are continually clipping the vegetation, very little of it matures and dies; thus, standing dead material does not accumulate in large quantities. As a result, the amount of material that eventually falls to the ground as litter is reduced, and bare ground increases (Coppock et al. 1983a). For example, Archer (et al. 1987) found that rapid changes occurred in the first two years following colonization, but by the third year, bare ground had stabilized at 35% (compared to ~10% initially) and litter cover had decreased to less than 10% (~20% initially).

Change in plant species composition after prairie dog occupation has been widely noted (Osborn and Allen 1949, King 1955, Koford 1958, Bonham and Lerwick 1976), but its rate of change has not been documented in detail. In separate colonies, Coppock et al. (1983a) and Archer et al. (1987) studied the rate of plant species change, replacement, and diversity. The rate of change, controlled in part by grazing pressure of prairie dogs and other herbivores, initial community composition, soil type, and weather, varied between colonies, but the trends were similar. In the most recently colonized areas (<2 yr), there was little change in plant species composition relative to uncolonized prairie. In areas of the colonies that had been impacted more than 3 yr, shifts in plant dominance and composition had begun (Coppock et al. 1983a) or had rapidly progressed (Archer et al. 1987). The dominant species in the uncolonized prairie, the midgrasses, were replaced by shortgrasses and annual forbs. Species diversity was highest in parts of the colonies occupied an intermediate length of time. Diversity in the oldest portions of each colony declined to levels similar to the uncolonized prairie due to the final dominance by a few species of forbs or dwarf shrubs.

PRAIRIE DOGS AND INTERACTIONS WITH OTHER ANIMALS

Thus far we have considered prairie dog interactions with the aboveground vegetation; however, prairie dogs are also creating patches within the ecosystem that modify densities, foraging patterns, and nutritional dynamics of other animals.

Prairie Dogs and Ungulates

Free-ranging populations of native grassland ungulates within Wind Cave National Park include about 350 bison, 60 pronghorn, and 400 elk. Early observations suggested that bison and pronghorn

were frequently associated with prairie dog colonies (King 1955, Koford 1958). More recently, Wydeven and Dahlgren (1985) reported summer use of prairie dogs colonies by bison, elk, and pronghorn. Our research has verified that there is selection for prairie dog colonies by both bison and pronghorn, and that this may incur some nutritional advantage to animals that feed on colonies (Coppock et al. 1983b, Krueger 1986, Vanderhye 1985).

In conjunction with studies on plant response to colonization, Coppock et al. (1983a,b) also investigated the parkwide selection of bison for prairie dog colonies, the pattern of use by bison within a colony, and the relationship between that and the dynamics of the plant communities on and off colonies. The park consists of approximately 6% prairie dog colonies, 74% uncolonized grassland, and 20% coniferous forest. If animals randomly use whatever habitat they encounter, the frequency of observations of those animals on a habitat will approximate the proportion of that habitat in the park. Our results showed that bison predominately use the grasslands and prairie dog colonies and, in summer, the use of colonies was much higher than would be expected by chance alone.

On an extensively studied colony, bison preferred specific sites for various activities (Coppock et al. 1983b). Over the growing season, bison used the (a) younger, grass-dominated portion of the colony for both grazing and resting (3.0 and 2.7 times expected, respectively), the (b) edge primarily for grazing (2.5 times expected), and the (c) forb/dwarf shrub-dominated older areas for resting (2.5 times expected). The amount of time spent resting on the edge of the colony and feeding in the oldest part of the colony was essentially random. They used the adjacent uncolonized prairie only 20% of the expected time for either activity, indicating that this area was avoided in preference for the colony. Similar utilization patterns have been observed on other colonies (Krueger 1986).

Although bison are relatively nonselective feeders (Schwartz and Ellis 1981), at least on the scale of a bite, they can choose the habitat in which they prefer to feed. When possible, an animal would be expected to feed in the most favorable locations, such as where nutrient levels and availability of the forage are high. As discussed earlier, prairie dogs modify grasslands such that plant material from colonies has a greater live to dead ratio (albeit lower standing crop), a higher crude protein (nitrogen) level, and a greater digestibility than from the uncolonized prairie, and this all implies greater nutrition per bite. The moderately impacted grass-dominated areas of the colonies are especially representative of these features. Thus, it seems reasonable to assume that prairie dogs have modified the environment making it a favorable feeding and resting habitat for other animals.

Vanderhye (1985) investigated nutritional benefits accrued to bison by selectively feeding on colonies by using Swift's (1983) model to simulate weight gains based on dietary information. Diet quality data were varied according to measured on and off colony values. Various patterns of colony usage, including random, typical, none, and 100%, were simulated. Averaged across all available studies, typical bison use of colonies during the growing season was estimated at 39% and random use was 12%. The model output suggested that if mature cows randomly use the colonies for feeding, they will gain an additional 2 kg (7% of seasonal weight gain) of body weight compared to not feeding on colonies at all. Typical usage of colonies confers an additional 5 kg (18%) weight gain. For yearling bison, randomly feeding on colonies could add 4 kg (14%) of body weight and typical use could add 13 kg (46%) beyond the gain expected when they avoid grazing on colonies altogether. The nutritional advantages are only realized from June through August when differences in forage quality between on- and off- colonies are maximal.

Elk (Wydeven and Dahlgren 1985) and pronghorn (Krueger 1986) also preferentially use prairie dog colonies. Krueger (1986) found that although both bison and pronghorn preferentially used colonies in summer, their location of use within the colonies differed. While bison preferentially used the grass-dominated areas, 57-97% of the pronghorn feeding on colonies were on the forb-shrub dominated centers. Within a preferred feeding area of the colony, there was a high dietary overlap between bison and prairie dogs and between pronghorn and prairie dogs. However, rather than competing for forage, the relationship between bison and prairie dogs seemed to be mutually positive, and between pronghorn and prairie dogs it was mostly neutral (Krueger 1986).

Prairie Dogs and the Belowground Ecosystem

Much of the plant system's dynamics occurs belowground and prairie dogs may influence the belowground responses of both plants and animals. It has been estimated that most of the energy flow in grassland systems occurs belowground (Coleman et al. 1976) and soil invertebrates, largely nematodes, may consume as much or more plant biomass as cattle on the mixed grass prairie (Smolik 1974). Because the root system provides a link for transport of materials from the soil to the shoot system, factors which affect the root system generally influence the aboveground plant dynamics as well.

Grazing typically reduces root biomass (Schuster 1964) because of reduced production and reallocation of material from roots to the regrowing aboveground shoots. There is marked decline in total root biomass from off prairie dog colonies to older parts of the colonies. In one study (Ingham and Detling 1984), soil cores were taken monthly from beneath A. smithii and S. scoparium on a heavily impacted section of the colony and in uncolonized prairie. Roots and nematodes were extracted from the cores. The seasonal mean root biomass from the colony was 70-80% of that off the colony, and total nematode densities were 45% higher on the colony than off. Nematode densities may reflect changes in soil microclimate or soil or plant chemistry caused by grazing. Annual net root production (ANRP) on the colony was about 60% of that off the colony; however, the percent of ANRP that nematodes consumed was estimated as 2.5x higher on the colony as off. Therefore, combining lower root production, higher nematode densities, and total consumption of roots on the colonies indicates a substantial impact and amount of energy and material flow occurring belowground.

Some Management Implications

As part of natural ecosystems, prairie dogs enhance certain features of the vegetation and create favorable habitat patches for other animals. Thus, in situations such as those described above for Wind Cave National Park, the presence of a limited number of prairie dog colonies scattered throughout the native grassland may improve the health and increase the diversity of other wildlife species. However, extensive utilization of prairie dog colonies by large herds of ungulates such as bison may accelerate changes in the vegetation via increased consumption rates and soil disruption and compaction by trampling and wallowing. This can reduce suitability of these sites for both bison and prairie dogs. Other research at Wind Cave National Park has shown that extensive bison utilization of such areas can be reduced by creating additional suitable bison habitat with controlled burns (Coppock and Detling 1986). It is necessary, however, to conduct the burns sufficiently far from prairie dog colonies that the burned areas will not provide additional habitat for rapid expansion of prairie dog colonies.

Caution should be exercised when extrapolating from the results of our studies in natural areas managed for wildlife preservation to rangelands managed for livestock production. While prairie dogs likely improve forage quality for cattle on rangelands just as they do for bison at Wind Cave National Park, it must be remembered that the areas with the enhanced forage quality have a lower total amount of forage available for consumption by livestock. Futhermore, it is common for significant portions of prairie dog colonies to be dominated by forbs, dwarf shrubs, or grass species which are unpalatable to livestock. Thus the increased forage quality in areas of colonies still dominated by grasses comes at the expense of a sizeable reduction in total available grass forage. While this may not be a problem when managing for wildlife populations at densities well below the carrying capacity of the land, it is a potentially larger problem in ranching operations in which livestock are maintained at levels closer to the carrying capacity.

Another consideration in managing for prairie dogs is one of scale. Much of our rangeland is divided into paddocks or pastures, and the amount of land available to cattle or other livestock is often not as extensive as that available to bison and other ungulates in parks such as Wind Cave. Therefore, it is conceivable that large proportions of individual paddocks may be covered by prairie dog colonies, thus reducing available forage far more than was observed in our studies in a natural area (Coppock et al. 1983a,b; Coppock and Detling 1986; Krueger 1986). Management policies for both domestic animals and prairie dogs should consider a number of factors including how much area is confined or available, animal densities, range condition and trend, opportunities for habitat selection, season of usage, and potential patterns of interactions.

FUTURE RESEARCH

Our research suggests that prairie dogs create unique patches of biological activity within grassland ecosystems. This patch structure is dramatically different from the surrounding grasslands, the behavior of other animals is modified by the presence of the patches, and changes in certain patch characteristics proceed in a fairly regular pattern through time.

Our current research is directed at further understanding some of the key ecosystem processes that determine the rates of structural and functional changes. We know that grazing by prairie dogs and associated herbivores decreases plant standing crop; however, does this necessarily imply decreases in net primary production? New green material with high nutritive value is being continually produced during the growing season on colonies, but are the rates of nitrogen (or other essential minerals) turnover and cycling different from those in uncolonized areas? Does extensive and preferential use colonies by several species of ungulates contribute to nutrient imports onto colonies via feces and urine, or is there a net offtake of nutrients? What happens when grazers are removed? How do other mobile herbivores, such as grasshoppers, respond to a patch structure that varies in time and space? At what point does a colony or part of a colony senesce, and do processes change or reverse? Answers to these questions are important for understanding the interactions of prairie dogs and their environment, and the role of herbivory as an influential moderator of ecosystem dynamics.

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A Statistical Model of Expansion in a Colony of Black-Tailed Prairie Dogs[1]

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Abstract.-- To predict prairie dog establishment in areas adjacent to a colony we sampled: (1) VISIBILITY through the vegetation using a target, (2) POPULATION DENSITY at the colony edge, (3) DISTANCE from the edge to the potential site of settlement, and (4) % FORB COVER. Step-wise regression analysis indicated that establishment of prairie dogs in adjacent prairie was most likely to occur when an area was near a densely populated colony edge with high visibility through the vegetation.

INTRODUCTION

In order to control black-tailed prairie dog (*Cynomys ludovicianus*) colony expansion, managers must be aware of the environmental conditions that promote the establishment of prairie dogs in previously unoccupied areas. Since the mid-1950's, environmental and biological factors linked to colony expansion have been studied and reasons for the growth of black-tailed prairie dog colonies have been suggested (King 1955, Koford 1958, Smith 1958, Garret and Franklin 1982, Uresk 1985, Knowles 1985a). The objective of our study was to test a set of hypothesized variables [(1) POPULATION DENSITY at the colony edge, (2) VISIBILITY through the vegetation, (3) DISTANCE from colony edge, (4) % FORB COVER], suggested through prior research of prairie dog ecology, as predictors of black-tailed prairie dog town expansion.

STUDY AREA AND METHODS

Field work was conducted during a 3 yr. study (1981-83) of prairie dog colony expansion in Badlands National Park, southwestern South Dakota. The study site was a colony of approximately 12 ha. located along the northern boundary of the Park. The colony was located on land formerly grazed by livestock. A large component of shortgrasses, especially buffalo grass (*Buchloe dactyloides*), was present in the mixed-grass type vegetation characteristic of the area (see Agnew et al. 1985 for a detailed description of fauna and flora of prairie dog colonies in Badlands N.P.)

Four variables were chosen with which to predict establishment of prairie dogs in adjacent uncolonized areas. These potential areas were mapped and marked in a grid system of 25 m. grid squares. In 120 grid squares (1981-82: 55 samples; 1982-83: 65 samples) beyond the edge of the prairie dog colony, we measured: (1) VISIBILITY through the vegetation using a 1 m. x 1 m. target observed within each grid square, (2) POPULATION DENSITY of prairie dogs at the nearest edge of the colony using the number of active burrows as an indicator of population numbers, (3) DISTANCE from the edge to the potential site of settlement, and (4) % FORB COVER using estimates from ten randomly placed plots (20 cm. x 50 cm.) in each grid. The target mentioned in (1) was bright orange with fifty, equally spaced 2 cm. white squares.

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Visibility was equal to the average percentage of white squares not obscured when observed from the center to the two outer corners (away from edge of colony) of the grid square (approx. 18 m.) and from a height of 0.5 m. above the ground.

A regression model was developed for colony expansion using these variables and their interactions. Variables were left untransformed. A step-wise linear regression procedure eliminated those variables from the model that failed to contribute significantly (using *F*-tests) to the regression sum of squares, determined by successive testing of the reduced models.

RESULTS AND DISCUSSION

The model selected by step-wise regression included, in order of relative contribution to the regression sum of squares, POPULATION DENSITY ($P<<.01$), VISIBILITY ($P<.01$), and the POPULATION DENSITY x VISIBILITY interaction ($P=.03$). Where $\hat{Y}$ is newly established presence (1), or absence (0) of prairie dogs in a grid square; X_1 is POPULATION DENSITY near the colony edge, and X_2 is VISIBILITY through the vegetation:

$$\hat{Y} = 0.1(0.02)^{A}X_1 + 0.01(0.004)X_2 - 0.001(0.0006)X_1X_2 - 0.2;$$
Pearson's $r=0.593^{*}$;

( )[A] *Standard error of coefficient,*
* *Regression significant at* $\alpha \leq .01$.

Results indicated that prairie directly adjacent to the study colony was likely to be colonized if it was near a dense population of prairie dogs and if there was high visibility through the vegetation.

Prairie dogs are likely to be sensitive to visibility because they depend heavily upon locating predators and using alarm calls to warn conspecifics (King 1955, Hoogland 1981). High population densities may force prairie dogs to expand into new territory. However, in other research conducted on the same colony most individuals that settled near population concentrations at the edges of colonies were from outside of the colony (similar observations were made by Knowles 1985a).

The presence or absence of forbs (% FORB COVER) did not contribute significantly to the regression model sum of squares. Analyses of prairie dog diets (Krueger 1986, Uresk 1984, Fagerstone 1982, Fagerstone et al. 1981, Summers and Linder 1978) have shown black-tailed prairie dogs to be remarkably adapted to foraging on a wide range of plant species and plant parts; prairie dogs are known to consume the flowers, seeds, leaves and roots of grasses as well as parts of a wide variety of dicotyledonous herbs and dwarf shrubs that flourish within black-tailed prairie dog colonies. Though not included in the regression model, DISTANCE from the colony edge is obviously important to prairie dog establishment, since new burrows were not observed more than 55 m. from an existing colony edge.

Significant differences (contingency table X^2; $P\leq.10$) in the "establishment success" of black-tailed prairie dogs occurred at short (11-25 m.), medium (26-40 m.), and long distances (41-55 m.) from the edge of the colony for grids grouped both by POPULATION DENSITY classes (fig. 1a) and by VISIBILITY classes (fig. 1b). Among POPULATION DENSITY classes (high and low), highest establishment success was observed in areas at short and medium distances from the colony edge when these areas were adjacent to high density populations (>50 burrow entrances/ha). Among VISIBILITY classes (high, medium, and low), highest establishment success was observed, once again, in areas at short and medium distances from the colony edge where high VISIBILITY (>30%) through the vegetation occurred.

Maintenance of a thick herbaceous cover has been suggested as a means of discouraging the rapid expansion of prairie dog colonies and even credited with the elimination of a small prairie dog colony (Osborn and Allan 1949, Snell and Hlavachick 1980). Visibility, as recorded using the target, has two components, (1) density of vegetation and (2) plant height. Management practices for vegetation along colony edges that maintain only tall plants without regard for high density stands, and *vice versa*, will probably prove ineffective; both components are necessary. Results of this study also suggest that colony expansion may be difficult to minimize without some control of prairie dog densities at the edge of the colony. Our research (Cincotta et al. [in press]) and other similar research (Knowles 1985a, Knowles 1985b, Garrett and Franklin 1982) suggest that expansion of colonies may be influenced by the proximity of other black-tailed prairie dog colonies that serve as pools for dispersers.

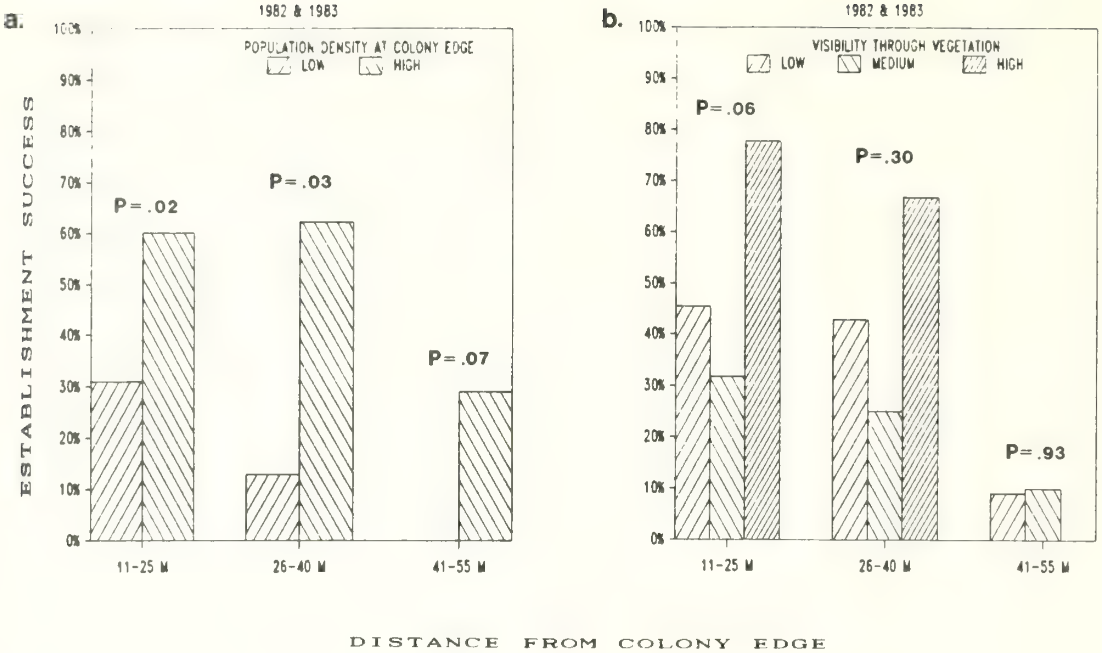

Figure 1.--The observed percentage of ESTABLISHMENT SUCCESS of prairie dogs in uncolonized grid squares adjacent to a colony. Squares were classed by the level of: a.) POPULATION DENSITY at the nearest colony edge, and b.) VISIBILITY through the vegetation. P-values represent the probability of homogeneity within the distance class (contingency table X^2).

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White-Tailed Prairie Dog Ecology in Wyoming[1]

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Abstract.--White-tailed prairie dog populations and habitats were studied on six towns in Wyoming. Habitats and habitat structure varied greatly both within and between towns. Prairie dog populations on each town were found to fluctuate by more than 50% between consecutive years. Prairie dog density was not significantly related to burrow density indicating that burrow density was not a useful predictor of population density.

INTRODUCTION

Although white-tailed prairie dog (Cynomys leucurus) ecology has been studied, most studies concentrated on various aspects of behavioral ecology (e.g., Hoogland 1979, 1981) or reproduction (Bakko and Brown 1967). Only two (Tileston and Lechleitner 1966; Clark 1977) dealt with population ecology. Even though aspects of white-tailed and black-tailed prairie dog (Cynomys ludovicianus) ecology may be similar (e.g., Clark et al. 1971), their life histories differ significantly (Tileston and Lechleitner 1966; Campbell and Clark 1981; Clark et al. 1982; Hoogland 1979, 1981). Knowledge of these differences are important in designing and implementing white-tailed prairie dog management programs.

In this paper we discuss the results of our study on the population and habitat ecology of white-tailed prairie dogs in two areas of Wyoming. We compare and contrast these data to similar data from the literature for black-tailed prairie dogs. We also discuss aspects of white-tailed prairie dog ecology that may be important in their management.

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STUDY AREA AND ANIMALS

We collected data on white-tailed prairie dog populations and habitats from six towns, three near Laramie, WY, and on three subcolonies of a prairie dog complex near Meeteetse, WY, in the Big Horn Basin. Both sites are on rolling plains interrupted by low hills and buttes (Bailey 1980). The study areas are in the Wyoming Basin Province (Bailey 1980) and are dominated by sagebrush (Artemesia spp.), greasewood (Sarcobatus spp.), wheatgrass (Agropyron spp.), and rabbitbrush (Chrysothamnus spp.). Plant species lists for all study sites are in Collins and Lichvar (1984, 1986). Study site elevations range from 2100 to 2200 m. Average monthly temperature ranges from 4 to 11 C, with average annual precipitation ranging from 125 to 350 mm (Bailey 1980). Cattle are grazed at varying rates on all grids.

White-tailed prairie dogs are large (800-1500 g), diurnal ground squirrels that inhabit high mountain basins in the Rocky Mountains of Colorado, Utah, and Wyoming (Hall 1981). They are social, and are found living in towns of various sizes, densities, and habitat characteristics. The white-tailed prairie dog's social system is similar to that of the Wyoming ground squirrel (Spermophilus elegans). It is not as complex as the social systems of the black-tailed and Gunnison's prairie dogs (Cynomys gunnisonii) (Michener 1983). Female white-tails are relatively sedentary. Juvenile males are the primary dispersing class, with dispersal occurring soon after initial emergence. Both sexes breed first as one year olds (Bakko and Brown 1967).

White-tailed prairie dogs hibernate during the winter (Harlow and Menkens 1986; Bakko and Nahorniak 1986) and follow the typical ground

squirrel emergence and immergence patterns. Adult males emerge in late February or early March (Bakko and Brown 1967; Clark 1977) with adult females emerging 2-3 weeks later. Breeding occurs soon after female emergence (Bakko and Brown 1967). Juveniles emerge in late May or early June, 5-7 weeks post-partum (Tileston and Lechleitner 1966; Bakko and Brown 1967). Immergence follows the opposite pattern. Adult males become sedentary and immerge during August, followed by adult females (mid-August to early September) and then juveniles (up until October) (Tileston and Lechleitner 1966; Clark 1977).

MATERIAL AND METHODS

Prairie dog populations were studied from 1983-1986 in Laramie and from 1984-1986 in Meeteetse. Habitat data were collected for all three years in Meeteetse, and for the years 1983-1985 in Laramie.

On each town, a grid (9 to 13 ha in size) was established for trapping and vegetation sampling. Prairie dogs were live trapped twice a year (June and August) for five days each month. They were individually ear tagged, and released. Chapman's unbiased version of the Lincoln-Petersen estimator (Seber 1982; Menkens 1987) was used to estimate population size. Percent cover by grass, forbs, subshrubs (mostly Artemesia frigida), and shrubs was estimated using point intercept sampling (Barbour et al. 1980) at 30 random points on each grid. Shrub density and height was estimated using line intercept techniques (McDonald 1980). Large scale (i.e., town wide) topographic variation was estimated from 1:100000 scale maps using a modification of Menkens and Anderson (1987). Small scale topographic variation (i.e., within grid variation) was estimated using a modified Robel Pole (Robel et al. 1970). All burrows greater than 10 cm diameter were censused in 1983 (Laramie grids) or 1984 (Meeteetse grids), total burrow density on all grids was estimated in 1986 by randomly sampling approximately 50% of the grid.

RESULTS AND DISCUSSION

Habitat

White-tailed prairie dog towns vary from being flat to those whose topographic heterogeneity index value is greater than 75% (Menkens 1987). Large scale topographic variation results because individual towns may contain hills that rise up to 20 m or more above the surrounding prairie. Towns may also be dissected by large gullies. The magnitude of large scale topographic diversity in white-tailed towns contrasts with the lack of such variation in black-tailed towns. Black-tailed prairie dogs seem to be limited to sites of less than 5% slope (Tileston and Lechleitner 1966; Knowles 1982)

Spatial variation in habitat variables, particularly shrub characteristics and topographic features, results in significant differences in inter- and intra-town habitat structural diversity (Tileston and Lechleitner 1966; Clark 1977; Menkens 1987). Shrub densities on towns range from a median of 0.0 to 3100 shrubs/ha and shrub height ranges from a median of 22 to 35 cm (Menkens 1987). Using our measure of within grid topographic variation, topographic diversity between towns ranges from 39 to 120%. Significant inter-town differences in topographic diversity results from the presence of small hills and gullies on some grids. The presence of many large maternity mounds (Clark 1977; Flath and Paulick 1979) on some grids but few on others, also contributes to topographic differences.

The degree of intra-town habitat diversity on white-tailed towns contrasts with the apparent lack of such diversity on black-tailed prairie dog towns. In addition to only inhabiting flat sites, black-tailed prairie dogs greatly modify the vegetation (and thus its structure) on their towns by clipping it to a short height and actively maintain this low stature (Tileston and Lechleitner 1966; Hoogland 1979; Coppock et al. 1983). White-tails do not visibly modify their habitats to the same degree. Because extensive vegetation modification by black-tails results in distinct town boundaries permitting easy delineation of towns from aerial photographs (Cheatheam 1973; Dalsted et al. 1981), it is possible to concentrate management efforts in well defined areas. Lack of visible habitat modification by white-tails, combined with their dispersed, uneven distribution throughout the habitat (Tileston and Lechleitner 1966; Clark 1977) makes town boundary delineation difficult. If white-tailed prairie dog management is to include poisoning, a knowledge of town boundaries is critical because incomplete treatment may lead to rapid recovery approaching pre-treatment population levels (e.g., Matschke et al. 1982; Knowles 1986). Boundary delineation may be accomplished using techniques and environmental features such as ground checking and mapping of the peripheral burrows, the use of gross topographic features (e.g., perennially flowing creeks, very steep slopes, etc.), and extensive soil barriers (e.g., alkaline soils, perpetually moist, or very sandy soils).

Since black-footed ferrets (Mustela nigripes) live on prairie dog towns, search techniques need to take into account habitat. The high degree of structural diversity, and prairie dog's dispersed populations will influence design and performance of nocturnal ferret searches on white-tailed towns (see Clark et al. 1984 for a description of this technique). While spotlight beams may extend up to several hundred meters on black-tailed towns; shrubs, tall grass, and hills and

gullies on white-tailed towns will greatly reduce the light's effective distance. Reduced sighting distance requires that more effort be expended on a town in order to obtain full search coverage. A lower limit of 10 burrows/ha has been recommended for defining town boundaries when conducting black-footed ferret searches (Forrest et al. 1985).

During this study, burrow densities changed significantly over time on only two towns while population densities changed on all but one (Table 1). On five of six towns, no apparent correlation existed between population and burrow densities (Menkens 1987). We also examined the relationship between population and burrow densities using linear regression on the pooled town population and burrow data for the first and last year of study. In both analyses (Table 1), the slope of the regression line was not significantly different from zero. These results also show that no significant relationship exists between burrow density and white-tailed prairie dog density. Although King (1955) did not explicitly test this relationship for black-tails, he reached the same conclusion. Thus burrow density on a town is not a reliable or useful predictor of either white-tailed or black-tailed prairie dog density.

Population Fluctuations

White-tailed prairie dog populations fluctuate greatly within towns (Clark 1977; Menkens 1987)(Table 2). The magnitude of temporal variation in density exhibited in this town (Table 2) is typical of the remaining five towns in this study (Menkens 1987). It can be seen that between year density changes can approach 50% or more. These changes are not predictable from habitat variables, climatic parameters, or from the previous year's density (Menkens 1987).

Density fluctuations have two impacts on management and control of white-tailed prairie dogs. First, they suggest that with potentially high reproductive output along with possibly high immigration rates (Menkens 1987), white-tails could recover from poisoning campaigns as rapidly (1-2 years) as do black-tails and Wyoming ground squirrels (Matschke et al. 1982; Knowles 1986). White-tailed prairie dog populations that have been nearly eradicated by epizootics of sylvatic plague (Yersinia pestis) have returned to pre-dieoff levels within four to five years (Barnes 1982).

The second effect of density fluctuations on white-tailed prairie dog management is that

Table 1.--Results of regressions examining the relationship between total prairie dog density and burrow density. BLM-13A grid excluded from the first regression because its burrow density was estimated whereas complete censuses were performed on the remaining grids in the first year of each study. All grids were included in the analysis of the final year's data. All population densities except Goulds differ significantly between the first and last year of the study. Burrow densities differ significantly between the first and last year of the study - for the Nunn and Pitchfork towns only. Burrow density in burrows/ha, prairie dog density in prairie dogs/ha. (from Menkens 1987).

First Year of Study (1983 or 1984)

Town	Burrow Density	Prairie Dog Density
Bath	106.3	9.1
Nunn	205.4	21.8
Pitchfork	65.3	4.3
Gould	106.0	17.1
91	84.7	18.4

Prairie Dog Density = 3.77 + 0.09 * Burrow Density
r^2=47.0 F=2.66 $p < 0.05$

1986

Town	Burrow Density	Prairie Dog Density
Bath	107.2 ± 13.9	15.3
Nunn	154.4 ± 28.2	7.6
Pitchfork	80.8 ± 13.1	12.3
Gould	88.9 ± 17.4	20.9
91	72.0 ± 13.1	9.9
BLM-13A	137.0 ± 21.7	2.0

Prairie Dog density - 23.3 = .11 * Burrow Density
r^2=32.1 F=1.89 $p < 0.05$

town boundaries or the boundary between active and inactive portions of the towns may shift between years. Thus, one must be aware of the difference between the town's physical and "biological" boundaries when designing management programs.

Table 2. Estimated white-tailed prairie dog densities (± 1SD) for the Gould town 1984-1986. Densities are given in prairie dogs/ha. Densities in the same row with the same numerical superscript are not significantly different at P = 0.05 using Fishers least significant difference (from Menkens 1987).

	Year		
	1984	1985	1986
Adults	7.7[1] (.7)	5.4[12] (.6)	4.6[2] (.6)
Juveniles	9.4[1] (.4)	8.4[1] (.8)	16.3[2] (2.1)
Total	17.1[12] (.8)	13.9[1] (1.0)	20.9[2] (2.2)

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Prairie Dog Overpopulation: Value Judgement or Ecological Reality?[1]

Kirsten Krueger[2]

Abstract.--The subject of prairie dog (Cynomys ludovicianus) overpopulation is complex, and judgements of overpopulation may not be based on prairie dog population size or density. Caughley's (1981) model of animal overpopulation is applied here to prairie dogs to clarify the basis for a judgement of overpopulation in each of several cases. There are ecological components to all such cases, but a purely ecological judgement of overpopulation requires much more information than is currently available. However, defensible management of prairie dog systems is a goal, and time-honored but flawed assumptions are never an adequate substitute for results derived from thorough, scientific studies of prairie dog systems as a basis for management actions.

INTRODUCTION

A general model delineating four classes of overpopulation was proposed by Caughley (1981) to clarify the ecological and nonecological values upon which judgements of overpopulation are based. In this paper I use Caughley's model as a framework for a discussion of prairie dog (Cynomys ludovicianus) overpopulation, within which I evaluate the reasons for such judgements in each of several cases. A purely ecological (class 4) judgement of overpopulation applies where prairie dogs cause a change in the typical dynamics and interactions of the plant-animal-soil system, and its structural and functional properties, to the extent that the system approaches or exceeds its boundaries, and is significantly altered from its initial condition. While all classes of overpopulation involve some ecological components, the three remaining classes subsume conflicts where the primary values (e.g., social and economic values) responsible for a judgement of overpopulation are nonecological.

CONFLICTS WITH HUMAN INTERESTS: CLASS 1 OVERPOPULATION

Socio-economic values associated with human interests, such as the maintenance of public health or healthy rangelands, dominate the public attitude toward prairie dog management. The two most frequently cited problems, plague (Yersinia pestis) transmission and competition with livestock for forage, have questionable significance based on available data. The human cases resulting from plague are so few as to be of no direct ecological consequence. [For example, 3.8% of 105 human plague cases in the United States, 1974-1980, were associated epidemiologically with C. gunnisoni and none with C. ludovicianus (Barnes 1982).] Prairie dogs are extremely susceptible to plague, and outbreaks among them are self-limiting (Barnes 1982). Prairie dog mortality typically exceeds 99% during plague epizootics (Cully 1986, Barnes 1982), after which the disease recedes or moves on, and normally does not regenerate for several years (Barnes 1982).

Recent evidence (Barnes 1982, Quan 1981) indicates that humans must go out of their way to contract plague from prairie dogs. Humans are thought to be incidental to the rodent-to-flea plague cycle because "ample exposure" to the disease during large-scale outbreaks among rodents in 1976 in Colorado produced no human cases (Quan 1981). Plague acquired from prairie dog sources normally results from direct contact with an infected animal rather than the bite of a prairie dog plague flea (Opisocrostis spp.), since the fleas rarely bite humans (Barnes 1982). In addition, the Plague Division of the Center for Disease Control currently has no evidence of prairie dog transmission of plague to livestock (Quan, pers. commun.).

Despite this evidence, the social value of a plague-free human population is undeniable, and prairie dogs are viewed as a threat in the

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western and southwestern states, where plague is endemic. However, judgements of overpopulation that are tied to this social value have no ecological basis, and prairie dog population sizes or densities may be largely irrelevant.

On rangelands, economic values seem to be the basis of overpopulation judgements because prairie dogs are viewed as competitors of livestock for forage. While this competition claim (Merriam 1902) is almost as old as ecology itself, it is unsupported by the empirical evidence. Recent examinations of the assumptions, methods, and results of animal competition studies have discredited conclusions asserting the presence and importance of competition in nature (Wiens 1977; Connell 1980, 1983; Strong 1983). These developments have important implications for the prairie dog-livestock conflict. Evidence such as simple prairie dog diet studies (see Fagerstone 1982) or studies of diet similarity or ecological overlap between prairie dogs and livestock (e.g., Hansen and Gold 1977) is now regarded as inadequate to demonstrate competition. More rigorous data are required. For example, a fundamental question where competition is suspected is whether or not the particular plant-animal-soil system shows stable population dynamics or whether unpredictable fluctuations are characteristic. Competition is expected more often under stable, equilibrial conditions where populations fluctuate in a density-dependent manner and where the food resource, in this case, is limiting. In such a system a negative interaction must be demonstrated among putative competitors. In addition, data must be obtained on spatio-temporal scales appropriate to the system and the question. Even when all these conditions are satisfied, competition may act only intermittently due to natural fluctuations in both biotic and abiotic components of the system. Thus, it is no simple matter to gather adequate data to convincingly demonstrate competition.

No such data exist for any prairie dog-livestock system, but O'Meilia et al. (1982) and Uresk and Bjugstad (1983) have addressed the interaction question with controlled field experiments. Their results suggest that prairie dog-livestock competition did not occur during their studies. For example, Uresk and Bjugstad (1983) reported higher peak standing crop on prairie dog-only than cattle-only treatments, and also that cattle plus prairie dog treatments had a higher peak standing crop than cattle-only treatments. This indicated that prairie dogs were not responsible for limiting cattle food supplies. Furthermore, O'Meilia et al. (1982) reported no significant differences in steer weight gain in pastures with and without prairie dog grazing, despite reduced herbage availability in pastures containing prairie dogs.

In fact, field experiments (Krueger 1986) and simulation modeling (Vanderhye 1985) have shown mutualistic interactions between prairie dogs and another large ruminant [bison (Bison bison)] and suggest the potential for a positive relationship between prairie dogs and cattle under certain spatio-temporal and habitat conditions.

Clearly, the direct and indirect effects of prairie dogs on livestock are not uniformly negative and could be positive in some situations. However, the potential for competitive interactions cannot be dismissed because previous results have been inconclusive, and may be especially great where livestock are maintained at unstably high densities for protracted periods, under spatially restricted conditions.

From the evidence reviewed above, judgements of overpopulation in cases of prairie dog-livestock conflicts do not appear to be examples of actual or potential class 4 ecological problems. Here, prairie dogs are assumed to be responsible for decreased revenues, but the assumption is unsupported. Although O'Meilia et al. (1982) indicated that the market value of steers grown on pastures with prairie dogs was somewhat less than that of steers grown on pastures without prairie dogs in their study, this conclusion stems from a logical flaw in their analysis. Their major result of no significant differences in weight gains between steers on pastures with and without prairie dogs showed differences in steer weights between the two groups to be statistically indistinguishable. Consequently, it is inappropriate to discuss the two groups as distinct, in market value or other comparisons. The unsupported assumption that prairie dogs are responsible for decreased revenues is itself based on prior unsupported ecological assumptions related to competition, although the potential for economic losses due to competition is certainly real, and the potential for competition sometimes high. As in the case of prairie dogs and plague, prairie dog population sizes or densities may be unrelated to economically motivated but ecologically unsupported judgements of overpopulation in prairie dog-livestock interactions, based on current evidence.

REDUCTION OF PREFERRED SPECIES: CLASS 2 OVERPOPULATION

Class 2 overpopulation applies where prairie dogs reduce densities of their plant and animal associates preferred by man, especially livestock forage species. Although this is an example of an indirect class 1 problem, it is directly a class 2 concern and therefore addressed here.

Recent studies have reported significant declines in the number of perennial species on prairie dog towns (Lerwidk 1974) and in the grass:forb ratio on portions of dog towns (Bonham and Lerwick 1976, Coppock et al. 1983, Krueger 1986), under combined ungulate-prairie dog grazing. Uresk and Bjugstad (1983) reported a slight (6%) decline in grass production on a prairie dog versus cattle grazing treatment. In

addition, Agnew et al. (1986) found fewer small rodent species on prairie dog towns than on undisturbed mixed-grass prairie, and concluded that prairie dog activities negatively affect rodents associated with the dense vegetation of uncolonized mixed-grass prairie.

In contrast, a number of studies have reported enhancement of prairie dog associates, including increases in plant cover, density (Uresk and Bjugstad 1983, Koford 1958, Bonham and Lerwick 1976), species diversity (Coppock et al. 1983, Bonham and Lerwick 1976), forage nitrogen concentration (Coppock et al. 1983, Krueger 1986) and digestibility (Coppock et al. 1983). Some animal species also show a positive response to prairie dogs. For example, Agnew et al. (1986) found increased densities of deer mice (Peromyscus maniculatus), grasshopper mice (Onychomys leucogaster), and bird densities and diversities on prairie dog towns. O'Meilia et al. (1982) reported increased small mammal and arthropod biomass on dog towns. Clark et al. (1982), Hansen and Gold (1977), and Uresk and Bjugstad (1983) found that prairie dogs improved habitat for any animals that are benefited by holes or short or sparse vegetation, such as burrowing owls (Athene cunicularia) and other birds, desert cottontails (Sylvilagus audubonii), rattlesnakes (Crotalis viridis), and other prairie dog predators.

While the depression or enhancement of preferred prairie dog associates can involve complex ecological interactions, these changes have not been shown to constitute class 4 problems. Nor are the changes uniformly negative. Judgements of class 2 overpopulation seem motivated by conflicts of economic values with putative monetary losses presumed due to prairie dog preemption of livestock forage. Like prairie dog-livestock competition, there is still no direct evidence to verify the assumption that where prairie dogs reduce the densities of livestock forage species, these reductions negatively affect lifestock or cause decreased revenues. The potential for negative ecological and economic effects from prairie dog reductions of livestock forage species is certainly real, and especially large where pasture size is limited and livestock densities maintained at high levels over protracted periods. However, without the necessary ecological evidence, class 2 economic judgements will continue to be based on unsupported economic and ecological assumptions. Prairie dog densities or numbers may again be largely irrelevant.

"FOR THEIR OWN GOOD": CLASS 3 OVERPOPULATION

No examples of the class 3 argument, that prairie dogs harm themselves by being too numerous or densely populated for their own good, have been reported. A class 3 argument would likely be invoked only where prairie dogs enjoy "protected" status, as in a national park or privately owned nature preserve.

In the absence of sufficient scientific study, and where population levels were presumed high, density-dependent effects such as rodent stress syndrome (Vaughan 1978) could be invoked to support the argument that individual prairie dogs were suffering from overpopulation. It is unknown whether prairie dogs are susceptible to stress syndrome, but considerable evidence suggests that some rodent species possess population self-regulatory mechanisms involving density-tolerant aggressive genotypes and density-intolerant dispersing genotypes (Vaughan 1978). In theory, prairie dog populations with these genotypes would be capable of density self-regulation and could potentially avoid the negative effects of rodent stress syndrome. Another argument, that of high ectoparasite load per individual (Hoogland 1979, 1981), could also be invoked to support a class 3 claim, but its ecological correlate, namely decreased predation risk per individual, compensates for negative effects of ectoparasites in prairie dogs (Hoogland 1981).

Thus, there is no current evidence to show that prairie dogs suffer as a direct result of high numbers or densities of conspecifics. Further study is needed to determine whether and when class 3 overpopulation applies to prairie dogs.

POTENTIAL ECOLOGICAL CRISIS: CLASS 4 OVERPOPULATION

A case of class 4 overpopulation will likely have socio-economic and political ramifications, but the judgement itself is based on purely ecological considerations. A class 4 judgement applies where prairie dog numbers or densities cause a change in the typical dynamics and interactions, and the structural and functional properties of the system, to the extent that the system approaches or exceeds its boundaries and is significantly altered from its initial condition. The information needed to define cases of class 4 overpopulation thus includes a knowledge of typical population dynamics and interactions of system components and how they vary, the location and character of system boundaries, and their relation to increases in prairie dog numbers and densities. None of this information is currently available for any prairie dog system.

Nonetheless, some theoretical possibilities exist. First, prairie dog populations may exhibit point or oscillatory equilibrial dynamics, at one or more stable levels, or their population densities might fluctuate in a stochastic manner (fig. 1) (Caughley 1981, Noy-Meir 1975, May and Beddington 1981, Sinclair 1981). Interactions among system components, such as plants and herbivores, may be tightly coupled and stable (fig. 2), unstable, or loosely coupled

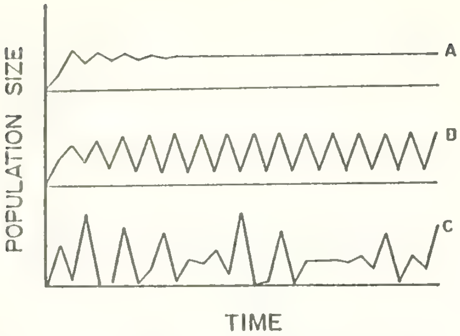

Figure 1.-- Types of population dynamics: (A) stable point equilibrium, (B) stable cycle; (C) chaotic flux (adapted from May 1981).

(Caughley 1981, May and Beddington 1981, Noy-Meir 1981, Sinclair 1981). Populations of plants and animals may fluctuate stably within system boundaries (fig. 3a) or above (fig. 3b) or below these thresholds (Noy-Meir 1981, Sinclair 1981). An upswing in prairie dog population densities or numbers may push the system to a breakpoint (May 1977) [perhaps a common occurrence in vegetation-herbivore systems (Noy-Meir 1981) and especially anticipated if prairie dogs were an ecological keystone species], beyond which the system either cannot return to its ground state (May and Beddington 1981, Walker 1981), or can return only with significant external input. If the system bounds are not exceeded, the components of the system would be expected to recede over time to equilibrium levels or to levels of stochastic flux within the original system boundaries. Alternatively, if the system bounds are exceeded due to a prairie dog population upswing, the structural and functional components of the original system are expected to shift to a condition that no longer constitutes the ground state. Rather, some alternate state is assumed. The system itself may contain several alternate states (fig. 4) (May and Beddington 1981,

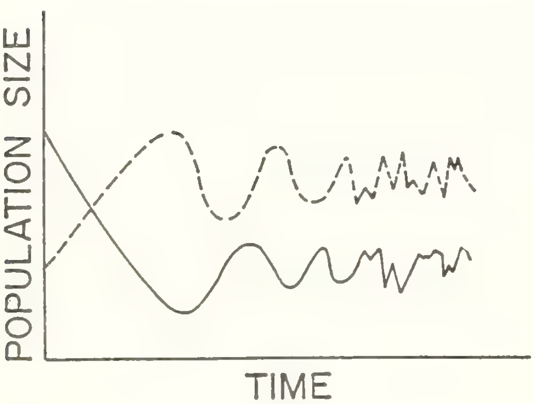

Figure 2.--Tightly coupled stable interaction between plant community (– – –) and herbivore population (———) (adapted from Sinclair 1981).

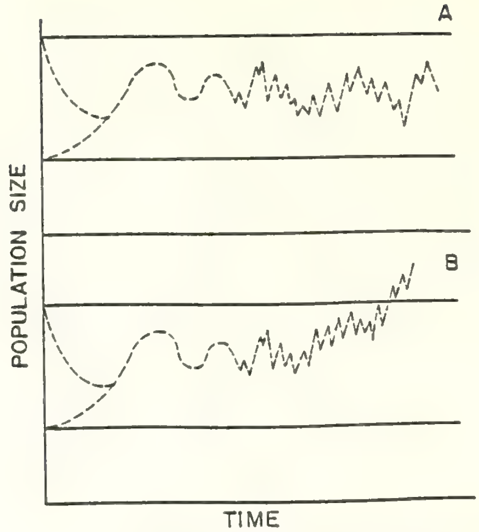

Figure 3.--(A) Region within which an herbivore population will return to the same equilibrium position; (B) herbivore population flux above upper threshold of system (adapted from Sinclair 1981).

Sinclair 1981) into which the shift may occur. Or the shift might be to a state outside the original system (fig. 5). Theorists speculate that these shifts will probably be deleterious, leaving the new system potentially irreversibly degraded (Noy-Meir 1981, May and Beddington 1981). Obviously, massive research efforts will have to be undertaken before class 4 overpopulation is understood for even one prairie dog system.

MANAGEMENT OF PRAIRIE DOG OVERPOPULATION

Although management of overpopulation will vary in each case according to the land-use goals and predominant values that have defined the type of overpopulation, the incorporation of ecologically defensible actions in management plans

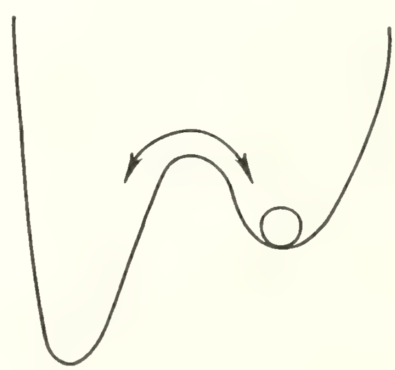

Figure 4.--Theoretical system containing two alternate states (after Noy-Meir 1975).

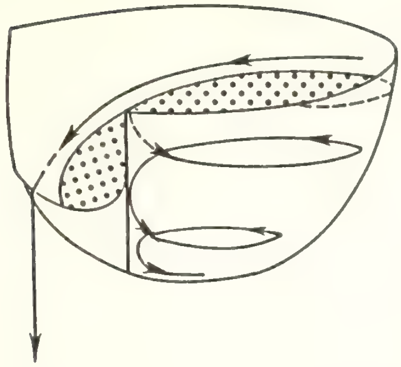

Figure 5.--Theoretical system undergoing shift to state outside original system, indicated by arrow leaving system domain (dish) (adpated from Holling 1973).

could enhance their success and facilitate the achievement of land-use goals.

For example, in cases of class 1 and 2 overpopulation, where prairie dogs appear to be in conflict with economic land-use goals, managers need to determine whether prairie dogs are actually causing economic problems by first studying the relevant ecological interactions closely. There is a critical need for correctly executed and interpreted studies of putative competition. Replicated field experiments at the appropriate local scale (Wiens 1986) represent the best way to demonstrate prairie dog-livestock competition. Experimental results can then be used to demonstrate related economic effects. Where prairie dogs are not implicated in economic and ecological declines, managers must suspect livestock as major contributors to such declines (Schenbeck 1986). Livestock densities are often held at unstably high levels (Noy-Meir 1981), which put the system at risk of long-term deteriorations, fluctuations or even state shifts. Prairie dogs may simply amplify a preexisting livestock-generated problem. Efforts to control prairie dogs where livestock are the primary offenders will not solve ecological problems and may increase rather than ease the land user's economic (Collins et al. 1984) and ecological burdens. However, where prairie dogs or prairie dogs and livestock are definitely responsible for depressed yield and income or are pushing the system toward its boundaries, prairie dogs must be reduced in a cost-effective manner and livestock densities concurrently reduced as well (Schenbeck 1986; see also Uresk et al. 1982, Snell and Hlavachick 1980, Snell 1985). In this way, long-term deteriorations or violent fluctuations in the system are avoided, and economic and ecological stability are promoted (Noy-Meir 1981).

In class 1 cases where plague is a concern, the self-limiting nature and transmission characteristics of the disease (Barnes 1982, Quan 1981) support a hands-off management policy. Because plague will come and go unpredictably through prairie dog populations, and because prairie dog populations themselves may have unpredictable dynamics, the most ecologically and economically sensible approach seems to be simply avoiding contact with plague-infested populations and plague-killed carcasses, rather than launching expensive eradication campaigns against prairie dogs or plague, since these campaigns normally have limited, short-term success (e.g., Barnes et al. 1972). However, where large human populations are in constant contact with plague-infested prairie dogs, continuous plague eradication campaigns may be the only viable management option given prevailing social values and concerns.

In cases of class 2 overpopulation, managers must first recognize that the inherently dynamic nature of ecological systems will inevitably result in some changes in the abundance of plant and animal associates of prairie dogs. Local extinction of some of these species might even occur as a normal event (Sinclair 1981). In general, reduction of a few plant species in an array of food types does not constitute grounds for a declaration of overabundance (Sinclair 1981). Furthermore, a "play-safe" policy that is too conservative in its estimates of permissible abundance for prairie dogs and their plant or animal associates may encourage the loss of resistant and resilient genotypes (Noy-Meir 1981) among these species, as well as declines in overall system resistance (Walker 1981). Where prairie dog reduction of preferred species is suspected, efforts similar to those required to demonstrate competition will be needed to demonstrate the role of prairie dogs in any such reductions, and whether there are any significant associated economic effects. As long as the changes in densities of prairie dog associate populations do not constitute prairie dog-induced class 4 overpopulation, or have proven economic significance, a management program that encourages maintenance of resistant and resilient genotypes and maintenance of system resistance is preferable to economically (Collins et al. 1984) and ecologically indefensible programs that potentially endanger the system and bankrupt the land owner over a period of years.

If class 3 overpopulation were demonstrated, managers necessarily would have to reduce prairie dog densities or numbers in accord with the prevailing (social) value behind this type of judgement, namely, the prevention of suffering among prairie dogs.

Examples of class 4 overpopulation are currently theoretical but have abundant socioeconomic and political implications for any cases empirically demonstrated in the future. The ecological consequences of a state shift caused by class 4 overpopulation are manifold and potentially long-lived, deleterious, and irreversible. Management of class 4 cases will likely be directed toward avoiding the potentially devastating consequences of a state shift into an

irretrievably degraded system and may be accomplished by reductions of densities or overall numbers of prairie dogs or other species responsible for pushing the system toward its limits. The fact that some class 1 and class 2 cases exhibit elements of class 4 overpopulation emphasizes the need for research on prairie dog population dynamics, the interactive dynamics of the components of prairie dog systems, and the location of system-specific boundaries in relation to these dynamics and interactions. These results would help managers recognize whether and when an ecological crisis might actually be at hand and help distinguish class 4 situations from the more prevalent but less critical class 1 and class 2 cases.

Clearly, socio-economic values and assumptions that are disconnected from the ecological realities of prairie dog systems can be the basis for flawed and indefensible judgements of overpopulation, as well as costly errors in management. In management plans, long-accepted assumptions are not adequate substitutes for results from thorough studies of prairie dog systems. Managers must use the knowledge gained from such studies to simultaneously promote socio-economic and ecological values and defensible prairie dog management over the long run so that land-use goals can be achieved.

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Efficacy of Deferred Grazing in Reducing Prairie Dog Reinfestation Rates[1]

Kelly A. Cable[2] and Robert M. Timm[3]

Abstract.--Population growth of black-tailed prairie dogs (Cynomys ludovicianus) was studied in 1985 and 1986 at 20 prairie dog towns on short- and mixed-grass rangeland in western Nebraska, to determine the efficacy of 2 years deferred (May 1 - Sept. 1) grazing in reducing population growth rates following population reduction. In 1985, population growth measures on deferred sites were not significantly different from grazed sites, perhaps due to drought conditions. In 1986, natality and population growth (% increase in animals) were significantly lower on deferred sites than on sites grazed by livestock. Deferred sites studied both years showed significant reductions in 1986 active area: 4 of 5 deferred sites decreased in size; 6 of 8 grazed sites increased in size. Results of this study suggest that deferred grazing may be effective in reducing reinfestation rates of prairie dogs following control, given favorable vegetative growth conditions.

INTRODUCTION

Historically a target of control efforts, prairie dog populations have been increasing since the institution of restrictions on the use of principal rodenticides in 1972 (Fagerstone 1982, Knowles 1982) and the cessation of federal animal damage control (ADC) activities aimed at prairie dogs. Legal control techniques typically employed to reduce prairie dog populations include poison bait application, fumigation, and shooting. Although these methods may result in immediate population reduction, they frequently do not produce a long term decrease in animal numbers for a particular site unless applied regularly. Repopulation of treated prairie dog colonies has been a recurring problem. On western U.S. Forest Service lands, retreatment of treated colonies appears to be necessary at least every 3 years (Schenbeck 1982). The necessity of frequent retreatment, and the cost of such control methods, have sparked interest in developing other methods of prairie dog population regulation or control. This paper presents the results of a study evaluating the efficacy of 2 years of deferred (May 1 - Sept. 1) livestock grazing in reducing reinfestation rates of black-tailed prairie dogs (Cynomys ludovicianus) on short- and mixed-grass rangeland in western Nebraska.

BACKGROUND

In recent years, there has been increasing interest in potential ecological relationships between prairie dog population growth and large ungulate grazing. The establishment and growth of prairie dog towns appears to be favored by intensive cattle grazing (Knowles 1982). Apparently, prairie dogs thrive best in short-grass habitats, or mid- and tall-grass areas which receive heavy livestock use. Knowles (1982) suggests that prairie dogs probably cannot maintain towns in mixed-grass habitat without the influence of large ungulate grazing, except if

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sites have inherently low productivity. It is theorized that the prairie dog's visual predator detection system is aided by the maintenance of short vegetation; additionally, it is possible that prairie dogs in taller vegetation may undergo some stress factor, or may have a reduction in natality brought about by nutritional shortages or social pressures (Snell and Hlavachick 1980).

The initial work investigating prairie dog - livestock grazing relationships suggests that the removal of livestock grazing from prairie dog towns may allow enough of a release from grazing pressure to result in a response from the vegetation. The increased vegetative growth, or response, appears to have a negative impact on prairie dog populations. Knowles (1982) observed that of 3 prairie dog towns (mixed-grass range) where cattle grazing had not occurred for 7 to 10 years, one town was inactive, and two were greatly reduced in size. Uresk and Bjugstad (1983) observed a reduction in active burrow densities when cattle were excluded from pastures with prairie dogs, which they attributed to the occurrence of taller vegetation. Uresk, et al. (1982) found that burrow densities in southwestern South Dakota on sites grazed by cattle increased at twice the rate of sites not grazed. An ungrazed exclosure on a town in mixed-grass appeared to contain a prairie dog population that was heavily dependent on immigrants to maintain animal numbers (Knowles 1982).

In an uncontrolled test, a 110 acre prairie dog town in Barber County, Kansas (25 inches average annual rainfall) was reduced to 12 acres in size following 4 successive seasons of deferred (June - August) livestock grazing (Snell and Hlavachick 1982). Located on a range site with the potential for mid-grasses, only short-grasses were observed prior to deferral, due to poor range condition. Snell and Hlavachick attribute vegetative recovery to dormant rootstock present. After 8 years, this town was 0.2 acres in size (Anonymous 1984).

Recent work in mixed-grass range of western South Dakota suggests that vegetative response to a release in grazing pressure may occur at a very slow rate. Uresk (1985) found that controlling prairie dogs did not result in a positive increase in forage production after 4 years. Uresk and Bjugstad (1983) suggest that total exclusion from herbivores (cattle and prairie dogs) for 9 or more years may be required to increase forage production when range is in a low condition class. Because of the observed slow vegetative recovery, it was theorized that any potential vegetative response to deferred livestock grazing in western Nebraska might be aided by concurrently reducing prairie dog grazing pressure through population reduction.

METHODS

Twenty and 18 prairie dog towns were used as study sites in 1985 and 1986, respectively. All of the sites were located in the short- and mixed-grass rangeland of western Nebraska (14 - 17 inches average annual precipitation). Deferral of livestock grazing was during the period of May 1 to Sept. 1; landowners were permitted to winter pasture livestock or hay deferred pastures Sept. - April. Cooperating landowners reported a range of 4 to 15 acres per animal unit month (AUM) livestock stocking rate on grazed pastures.

All of the sites had reduced prairie dog densities (1.5 - 10.9 adults/ha) through one or a combination of 3 methods applied within 2 years of the onset of the study: shooting, poison bait application, or fumigation. Three measures of population growth (increase in animal density, % increase in animals, and pup:adult ratio) were based on visual population censuses conducted in spring and late summer. Pup:adult ratio was treated as an indication of natality, and was based on the spring census. Increase in animal density and % increase in animals were based on growth in terms of the difference between the number of adult prairie dogs present on sites in spring, and the total number of prairie dogs present in late summer. These 2 population growth measures incorporate but do not discriminate between natality, immigration, emigration, and survivorship during that period. Town areas (ha) were measured in June of each year by mapping the outermost active prairie dog burrows.

RESULTS AND DISCUSSION

In 1985, no significant differences were found between treatments for any of the population growth measures (see Table 1). In 1986, 2 of the 3 population growth measures were lower for the deferred treatment than for the grazed treatment. Pup:adult ratio and % increase in animals were significantly lower on deferred sites than on sites grazed by livestock ($P>t=0.06$ and $P>t=0.02$, respectively). Statistical comparisons of population growth measures between years of the study are probably not valid, because environmental conditions affecting prairie dog populations varied considerably. However, examination of mean growth values (Table 1) reveals that all 3 population growth measures increased from 1985 to 1986 on grazed sites, whereas all growth measures decreased on deferred sites. Precipitation received at study sites did not differ significantly between treatments, but did differ between study years ($P>|t|=0.001$). 1985 was a dry year in the Nebraska Panhandle, and some study sites received as little as 55% of the normal rainfall. 1986 was a much wetter year, with many study sites receiving normal or slightly above average rainfall.

Change in town size is a growth measure of interest to landowners, who may equate extent of damage with extent of colony area. However, change in town size does not necessarily reflect degree of damage to rangeland vegetation, which may vary with prairie dog density, and does not necessarily reflect other measures of population

Table 1.--Population growth values.

Population growth measure	Year	N	Trt.	$\bar{X}$	S.D.	Range
Increase in animal density	1985	8	D[1]	9.9	9.7	0.0 - 26.9
Increase in animal density	1986	8	D	6.6	6.6	0.0 - 17.2
Increase in animal density	1985	12	G[2]	5.7	4.6	1.6 - 13.8
Increase in animal density	1986	9	G	8.9	4.5	3.3 - 17.0
% Increase in animals	1985	8	D	148.8	88.4	0.0 - 259.0
% Increase in animals	1986	8	D	87.0	80.9	0.0 - 242.0
% Increase in animals	1985	12	G	152.6	97.3	82.0 - 416.0
% Increase in animals	1986	9	G	179.6	88.3	67.0 - 363.0
Pup:Adult ratio	1985	8	D	2.2	1.0	1.0 - 3.7
Pup:Adult ratio	1986	8	D	1.4	0.9	0.1 - 2.4
Pup:Adult ratio	1985	12	G	1.8	1.1	0.0 - 4.2
Pup:Adult ratio	1986	9	G	2.1	0.9	0.7 - 3.8

[1]D = deferred
[2]G = grazed

growth. Active areas of sites ranged from 0.4 to 20.3 ha. Active areas for deferred treatment sites decreased significantly from 1985 to 1986 (P>t=0.07): 4 of the 5 deferred treatment sites used in both years of the study decreased in area inhabited by prairie dogs, with a mean decrease on the 4 declining towns of 49%, and mean overall change in size of the deferred treatment towns of -37%. Conversely, 6 out of 8 grazed sites increased in active area (P>t=0.04), with a mean increase on the 6 expanding towns of 42%, and mean overall change in size of grazed treatment towns of +25%.

A decrease in area inhabited by prairie dogs does not necessarily imply a decrease in prairie dog numbers or density: town contraction may result in a net increase in density. One study site decreased 51% in active area from 7.2 ha in 1985 to 3.5 ha in 1986. However, number of spring adult prairie dogs increased from 12 (1.7 adults/ha) in 1985 to 21 (6.0 adults/ha) in 1986, a net increase in animals of 43% and a net increase in density of 253%. Knowles (1982) observed a 47% increase in acreage over a 2 year period, with a concurrent decline in density of 30.6 to 19.6 prairie dogs/ha. Knowles noted the change in density appeared to be correlated (r^2=0.85) with precipitation: two dry years occurred with low vegetative production, and the prairie dogs expanded into adjacent, abandoned areas. Rainfall would not appear to be the sole controlling factor in western Nebraska, because precipitation did not differ significantly between expanding and nonexpanding towns. However, the combined influence of rainfall and livestock grazing on vegetation may have contributed to changes in town area. Low 1985 precipitation and livestock grazing and trampling would tend to result in low height and density of grazed-site vegetation, and encourage expansion by prairie dogs into adjacent areas. Absence of livestock grazing on deferred sites, in combination with high 1986 precipitation, may result in greater vegetative height and density on deferred sites, and discouragement of prairie dog expansion.

Visual observations on deferred treatment sites suggest that as town area contracts, prairie dog activities become less generally distributed across colonies, and clumps, or centers of activity result. These clumps of prairie dogs appear to be separated by relatively taller, sparse vegetation.

MANAGEMENT IMPLICATIONS

Results from this study suggest deferred grazing may be an effective management tool in reducing prairie dog reinfestation rates. The efficacy of deferred grazing in the mixed- and short-grass rangeland of western Nebraska would appear to be heavily dependent on rainfall. Below average rainfall would appear to limit vegetative response to a release from grazing pressure, and result in prairie dog population growth rates similar to those seen on sites with higher grazing pressure. The efficacy of deferred grazing would also be expected to vary with the natural productivity capacity of specific sites.

Within the constraints of the study (i.e. town size 0.4 - 20.3 ha; 1.5 - 23.6 adults/ha), colony size and initial prairie dog density would not appear to reduce the efficacy of deferred grazing in reducing population growth rates of prairie dogs. However, large towns and prairie dog densities more typical of uncontrolled towns were not studied. The ability of high prairie dog densities to limit potential vegetative response to removal of livestock grazing pressure may

exist. If so, the application of deferred grazing is probably most efficacious as a method of reducing population growth when applied soon after population reduction.

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Management of Prairie Dog Populations in Wind Cave National Park[1]

Richard W. Klukas[2]

Abstract.--Since the late 1920's there have been periodic control programs on black-tailed prairie dogs in Wind Cave National Park. The most recent control effort, which began in 1982, resulted in the reduction of total dogtown acreage from 2,000 to 750 acres. Recent studies carried out within the park have provided managers with more soundly based justification for carrying out control programs. The same information also points to the importance of maintaining prairie dog populations at or above certain minimum levels and the need for integrating this control program with several of the other resource management programs being carried out in the area.

INTRODUCTION

In 1903 the United States Congress established Wind Cave as a 10,840 acre national park. The area was set aside due to its cave resources and for the potential which it held as a reintroduction site for species such as elk, bison and pronghorn. Additional lands were added to the park over time so that by 1946 its boundaries encompassed roughly 28,000 acres.

As the park grew its ungulate herds (bison, elk and antelope) were allowed to increase in size. The earliest wildlife management activities centered on regulating bison and elk herd sizes and controlling predator species such as coyotes and bobcats. Black-tailed prairie dogs (Cynomys ludovicianus) were also considered to be in need of regulation as evidenced by sketchy accounts and records in park files dating back to the 1920's and 1930's. In those early years management of wildlife populations deemed to be in need of control was based largely on instinctive reactions, and trial and error experiences. In recent years the development of ecological concepts and understandings, as well as their application, has led not only to a tolerance of the prairie dog but to an appreciation of its role in maintaining a dynamic natural setting for other native plants and animals.

[1]Paper presented at the 8th Great Plains Damage Control Workshop. (Rapid City, SD, April 28-30, 1987).

[2]Richard W. Klukas is a research biologist at Wind Cave National Park, Hot Springs, South Dakota

These new insights and a vastly improved attitude toward prairie dogs would not have come about were it not for a considerable number of recent studies which have been recently conducted both within Wind Cave and adjacent areas. The primary purpose of this paper is to discuss some of this recent work and describe a possible future course for the management of black-tailed prairie dogs in Wind Cave National Park.

RESEARCH FOCUSED ON MANAGEMENT QUESTIONS

Most prairie dog studies in the park have been conducted by graduate and post-graduate researchers. In nearly all cases the immediate study goals of these persons were not focused on answering questions that were of concern to managers. Nevertheless their work often produced information that allowed for important insights far beyond what was anticipated. Such findings will be discussed later in this paper. The National Park Service however, has carried out studies which dealt primarily with problems and questions perceived to be critical to the establishment of a suitable prairie dog management program. These studies were carried out through research contracts or by park personnel.

With respect to the prehistoric occurrence of dogtowns, Carlson (1986) and White (1986) determined that prairie dog colonies have been present on lands within the park for at least the past several thousand years. In addition, White speculated that dogtowns appear to have contracted, expanded or were abandoned or recolonized depending on major shifts in climate.

Garrett and Franklin (1982) studied movements of prairie dogs (immigration) to determine the extent that prairie dogs from the park might contribute to the establishment and growth of towns on lands beyond its boundaries.

Garrett and Franklin (1982) in addition experimented with visual barriers as a means of reducing, halting or directing the expansion of dogtowns.

Garrett and Franklin (1983) and later Klukas (unpublished) used Diethylstilbestrol (DES) to determine if prairie dog population management could be achieved by limiting natality. Population regulation through use of smoke bombs, rim and center fire rifles and zinc phosphide was also tested by park personnel. Among all the approaches to control that were tested, that involving the use of zinc phosphide treated baits proved most effective and practical.

OTHER STUDIES RELATING TO PRAIRIE DOGS

The earliest prairie dog research carried out in Wind Cave was a study on behavioral and life history characteristics by J. A. King in 1955. J. Hoogland came to the park in the mid 1970's to explore more fully the behavioral characteristics of blacktails and continues at present in that pursuit. King and Hoogland have uncovered a substantial body of information of importance to other researchers (i.e. ecologists, behaviorists, geneticists, etc.) as well as to those interested in the management of prairie dog populations (King 1955, Hoogland 1979, 1981, 1985).

Coppock was among the first of many ecologists who was able to enhance their investigations through use of information obtained from earlier studies by King and Hoogland (Coppock, et al, 1983). Coppock and associates' determination that prairie dogs were affecting bison grazing patterns led to a number of subsequent related studies by fellow graduate students and staff of the Natural Resources Ecology Laboratory at Colorado State University. Among the findings of this group were that: prescribed fire can be used to reduce bison grazing activities on dogtowns (Coppock and Detling 1986); and that summer grazing of dogtowns by bison offered significant nutritional advantages (Ravndal 1985). These and various other findings of no less significance are described more fully in another paper to be presented at this workshop by James Detling and April Whicker (see: Control of Ecosystem Processes by Prairie Dogs and Other Grassland Herbivores).

While many of the above behavioral and ecological studies were being carried out by visiting researchers the National Park Service was undertaking studies to determine the importance of prairie dogs as a food source for predators. During the period 1975 to present 38 prairie dog predations were observed and recorded. Although six predator species contributed to this total only the coyote, with 17 predations (45%), appeared to demonstrate somewhat of a reliance on the prairie dog as a dietary subsistence item. A concurrent study on coyote food habits by Franklin et al (in writing) appears to verify this assumption.

MANAGEMENT CONSIDERATIONS

The array of research findings referred to so briefly above have generated a considerable body of information which can be utilized in a number of ways within Wind Cave National Park. Interpretation based on new information on prairie dog behavior, and natural history and the role of prairie dogs as a key component of the ecosystem can be upgraded and enriched for presentation to the public.

This same information, viewed from a different perspective, can be applied to the improvement of Wind Cave's prairie dog management program. Modifications of the current program can be guided by a number of important considerations brought to light by recent research. Some of those which seem to be most relevant are as follows:

1. Prairie dog colonies on park lands have varied in size, number and importance through a good portion of the post-Pliestocene period.

2. There are significant interactions between prairie dogs and associated plants and animals. These interactions include not only modifications of feeding, growth, and behavioral characteristics but may be of evolutionary significance as well.

3. Natural predation of prairie dogs does not occur with enough frequency to exert a controlling influence on any but the smallest sized colonies. With the possible exception of the badger there appears to be no predator species which is strongly reliant on the prairie dog as a food source.

4. There are no practical, indirect or non-toxic approaches to control of prairie dog populations that alone can fulfill all the requirements for accomplishing such within the park.

5. Fire can be used to stimulate the growth of dogtowns as well as to temporarily halt their rate of growth or to even reduce their size. Prescribed burns immediately adjacent to dogtowns can enhance dogtown expansion by reducing the height and density of bordering ground cover. Fires on areas removed from dogtowns will significantly reduce ungulate use of colony sites. Under such conditions prairie dogs must on their own accomplish the reduction of ground cover required for expansion into uncolonized areas.

6. High populations of elk, bison and perhaps pronghorn, along with absence of fire and less than normal precipitation during the plant growing season provide optimal conditions for expansion of dogtowns.

The above considerations in concert imply that there is a need for modification of the park's current prairie dog management program. A revised program should clearly demonstrate a recognition of the essential role of prairie dogs in catalyzing or promulgating many important ecological and evolutionary processes. Control of prairie dog colony

sizes and locations needs to be reconsidered. The current program calls for reducing total acreage to 700 acres and limiting the number of colonies to five. A more flexible or dynamic approach would appear to be justified by the considerations discussed above. Colony sites which have been unoccupied for decades should be allowed to grow to their former size when recolonized. Other colonies which have been occupied for many decades could be depopulated for a period long enough to permit the return of a ground cover more typical of uncolonized areas. Total acreage should be allowed to fluctuate between 700 to 1200 acres and numbers of active colonies could be as high as ten.

The long interval between the most recent reduction (1982-1986) of total colony acreage and the previous such effort (mid-1950's) was perhaps the most important factor contributing to the unprecedented recent high level of dogtown acreage (2,000+ acres) within the park. Future efforts to control the size and locations of colonies should be carried at intervals no longer than five years. In all forthcoming management plans it will also be necessary to consider the use of indirect (prescribed fire and ungulate herd size reduction) as well as direct (zinc phosphide and rifles) control measures.

Current and future research efforts will likely provide information that will point to the need for further refinements and modifications in the prairie dog management program. Experiences gained in managing prairie dogs over many decades and information obtained from recent intensive research efforts point to the necessity of viewing prairie dog management as a dynamic, ever evolving but never static, program.

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An Evaluation of Shooting and Habitat Alteration for Control of Black-Tailed Prairie Dogs[1]

Craig J. Knowles[2]

Abstract. - Shooting at two incipient black-tailed prairie dog (Cynomys ludovicianus) colonies removed from 12.8 to 17.3 prairie dogs/ha with reduction of adults averaging 69%. Habitat was physically altered in a portion of one prairie dog colony and activity levels between treated and non-treated areas did not show any consistent differences.

Introduction

Research on prairie dog (Cynomys sp.) control is usually directed towards the use of toxicants. Toxicants such as zinc phosphide, when properly applied, are considered efficacious (Tietjen 1976). Shooting of prairie dogs, because of its sporting value, has often been suggested as an alternative form of control. Recreational shooting of prairie dogs has been a part of a Bureau of Land Management (BLM) prairie dog management program in north-central Montana for several years now (USDI BLM 1982). Aside from anecdotal accounts there is little information on the population consequences of shooting on prairie dog numbers.

Habitat alteration of prairie dog colonies has also been considered as an alternative method of control. Fagerstone et al. (1977) treated a prairie dog colony with 2,4-D to alter plant species composition but found no effect on prairie dog activity levels. Snell and Hlavachick (1980) and Snell (1985) reported prairie dog numbers to decline following initiation of a deferred grazing system. In this case, increased vegetative cover was thought to result in increased predation. Physical treatment of a prairie dog colony to provide hunting advantages to predators may be a useful control technique in certain situations.

The purpose of this study was to examine the effects of shooting and habitat alteration on black-tailed prairie dog colonies on the Charles M. Russell National Wildlife Refuge in north-central Montana.

[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop. [Rapid City, SD, April 28-29 1987].

[2]Craig J. Knowles is a wildlife ecologist, FaunaWest Wildlife Consultants, Boulder, Mont.

Study Area and Methods

This study was conducted on the Charles M. Russell National Wildlife Refuge in north-central Montana from 1978 to 1980. The Refuge was typified by rough, broken country interspersed with rolling prairie. Prairie dog colonies on the Refuge were restricted to the shrub-grassland and grassland habitats located on broad level ridge tops or on bottomlands of the major drainages. The management goal of the Refuge for prairie dogs at the time was to control the size of certain prairie dog colonies but not to exterminate them.

Shooting as a control technique was evaluated at two colonies (Colony A - 5.9 ha, and Colony B - 1.4 ha). Shooting was conducted in the last half of June 1978 using a 0.22 caliber rifle while in 1979 shooting started in mid-May and continued until early August using a 0.22 caliber magnum rifle. Shooting in Colony A was generally from a portable blind while shooting at Colony B was from a pit dug into a ridgeside overlooking the colony. Notes were made as to the beginning and ending times of a shooting period, number of shots taken, and number of prairie dogs deemed hit. Population surveys were made prior to, and immediately after shooting both years plus one additional survey in June 1980. Visual counts of prairie dogs were made five times at 15-minute intervals on each of three different morning or evening activity periods. The largest of the 15 counts was then selected as the count that most closely approximated the actual number of prairie dogs (Knowles 1986). Percentage reduction of prairie dogs was based on adults since the pre-treatment survey period in 1978 and the shooting period in 1979 occurred during a period of juvenile emergence.

During the summer of 1978, a 2-ha area of a 24.6-ha colony received a habitat alteration treatment designed to provide more hiding cover for mammalian predators and perches for raptors. About one dozen piles of driftwood logs from Fort

Peck Reservoir, were placed in the treated area. Several freshly cut ponderosa pine (Pinus ponderosa) were dragged into the treated area and numerous small (0.5 m high, 1-2 m long) rock piles were placed in the colony. In addition, 10, 4.3 m telephone poles were placed in the treated area as raptor perches. In the fall of 1978, 18 depressions (0.3 m deep) and mounds (0.5 m high) were made with a bulldozer. In early May 1979, 40 bales of old hay were also placed in the treated area. Change in horizontal visibility as a result of this treatment was determined with a cover board (see Knowles et al. 1982). Efficacy of the habitat alteration was measured by plugging with soil 100 burrows in each the treated and non-treated sections of the colony. Burrows were examined 48 hr later making note of the number of burrows opened.

Results and Discussion

Approximately 17 prairie dogs per hectare were removed by shooting at Colonies A and B in 1978 (table 1). In 1979, a similar number of prairie dogs were removed from Colony A but considerably less were taken at Colony B as a result of an already reduced population. Percent reduction in adult prairie dogs for 1978 and 1979 were 67 and 62 for Colony A, and 46 and 100 for Colony B, respectively (table 2). Estimated density of all surviving prairie dogs in 1978 and 1979 were 8.8 and 5.6/ha at Colony A, and 10.0 and 0.7/ha at Colony B, respectively. Only one juvenile prairie dog remained in Colony B in 1979 after 6.1 hr of shooting effort. Densities during these two years at two untreated colonies where prairie dogs were trapped and marked (Knowles 1982) were estimated at 30.6 and 8.3/ha in 1978, and 24.6 and 19.3/ha in 1979.

Table 1. -- Shooting effort and prairie dogs removed at Colonies A and B in 1978 and 1979.

Colony Year	Hours at colony	Shots	Dogs hit	Dogs removed/ha
Colony A				
1978	22.8	503	99	16.8
1979	36.4	239	102	17.3
Colony B				
1978	17.5	217	23	17.0
1979	6.1	30	16	12.8

Table 2. -- Maximum number of adult prairie dogs present pre and post-shooting at Colonies A and B from 1978 to 1980.

Colony	1978 pre	1978 post	1979 pre	1979 post	1980 post
A	66	22	45	17	28
B	15	8	3	0	6

Both treated colonies showed strong population recovery trends in 1980 in the absence of shooting (table 2). Immigration into Colonies A and B probably augmented the population in all years as both colonies were located along a dirt road 1.0 and 2.8 km from a 100-ha colony (see Knowles 1985 concerning the relationship of roads to prairie dog dispersal). This was certainly the case for Colony B during the shooting period in 1979 and in June 1980. In the latter case, 6 adult prairie dogs were present when, at most, only one of these could have been a survivor from the previous year. The adult population in Colony A in 1980 was 42% of the 1978 pre-treatment population.

Effort levels between years were not comparable as shooting strategies changed. In 1978, the standard 0.22 rifle which was used for shooting caused only moderate wariness in the prairie dogs and allowed for many shots to be made at ranges where accuracy was poor (5.9 shots/prairie dog). In 1979, the 0.22 magnum used for most of the shooting increased accuracy greatly but resulted in increased wariness in the prairie dogs (2.3 shots/prairie dog). The BLM (USDI BLM 1982) estimated that with an average of 725 hunter days per year expended on shooting prairie dogs in Phillips County, Montana, 100,500 rounds of ammunition were fired resulting in the removal of 10,050 prairie dogs from about 400 ha.

Both Colonies A and B, which were established prior to 1973, were expanding before initiation of this study. Shooting appeared to be effective at lowering prairie dog densities to less than 6/ha and negating colony expansion. This was accomplished with only a moderate level of effort. In the case of the smaller colony, shooting appeared capable of removing all prairie dogs. Portions of both colonies were inactive during 1979 and 1980. However, by 1984, Colony A had expanded to 140% of its 1978 size and Colony B had expanded by 90%. In another small colony on the Refuge, 12 prairie dogs were removed by shooting in the spring of 1975. The three remaining prairie dogs were eliminated by natural causes by late fall of that year. This colony site had not been re-colonized by 1984 (year of last survey). Lewis et al. (1979) thought 10 - 20 prairie dogs were needed to start a colony.

Possibly the reduction of prairie dogs below a certain threshold number may have a negative population consequence (Allee's Principle, Allee et al. 1949) because fewer prairie dogs are available to watch for predators (Hoogland 1981) and keep the vegetation clipped around burrows.

Stockrahm (1979) reported on population structure of two colonies thought to be heavily shot at and two receiving little human exploitation. She found fewer males, smaller litters, and a low percentage of breeding among yearling females at the colonies that received heavy shooting. The latter two findings were opposite of what was expected (principle of inversity, Errington 1946), and she thought disruption of the social system might be responsible.

Shooting as a management program to contain specific prairie dog colonies (especially incipient colonies) may be effective if properly administered and a large number of shooting enthusiasts are available. A major advantage of this control technique would be its low cost, since labor and equipment are supplied on a voluntary basis. The following suggestions may make such a program more effective. 1) Shooting during spring while females are pregnant or lactating (March - May, see Knowles 1987), would have the greatest impact on the population with the least effort. 2) Use of accurate small caliber rifles are preferred to larger caliber guns. 3) Use of blinds (especially if entered at sunrise) reduces the wariness of prairie dogs, although prairie dogs ultimately learn to respond to the noise of guns. Additional research is needed to determine the effectiveness of this control technique on a management basis, and to evaluate its impact on non-target wildlife species using prairie dog colonies.

Horizontal visibility in the habitat alteration experiment was reduced from 89% to 78% in the treated portion of the colony. No consistent differences in activity levels were noted between the treated and non-treated sections (table 3). However, my general impressions in April of 1979 were that few prairie dogs were present in the treated area and that some prairie dogs moved into the treated area during the spring dispersal period. I was unable to visit this colony in April of 1980 to make comparable observations. The physical change of the treated portion of the colony did not appear to deter prairie dogs from using the area. Prairie dogs were frequently seen on top of rock or log piles and to use burrows under the raptor perches. A greater reduction in horizontal visibility was probably needed to truly impact prairie dogs. Elsewhere on the Refuge, prairie dogs were found to exist in areas with visibility values as low as 67%. Immigration into the treated area may also have served to equalize activity levels between sections of the colony.

Table 3. -- Number of burrows opened 48 hr after plugging 100 burrows each in the treated and non-treated portions of the colony receiving habitat alteration.

	1978	1979			1980	
	June	June	Aug.	Oct.	June	Aug.
Trt.	33	59	18	10	36	18
Non-trt.	37	55	31	15	40	23

American Kestrels (*Falco sparverius*) were the only raptors seen using the perches. The treated section of the colony was heavily used by Mountain Bluebirds (*Sialia currucoides*) and Mourning Doves (*Zenaida macroura*) which probably served to attract the Kestrels. Golden Eagles (*Aquila chrysaetos*) and Red-tailed Hawks (*Buteo jamaicensis*) were observed in the area but not in the colony. Northern Harriers (*Circus cyaneus*) hunted the colony in 1979 but they did not use the perches nor could they be considered a predator of prairie dogs. I did not observe any mammalian predators making use of the obstacles, although a Refuge employee did observe a bobcat (*Felis rufus*) hiding at the edge of the treated section.

Had the habitat alteration treatment been applied to the entire colony to reduce chances of immigration into the treated area, results of this experiment might have been different. It may be possible that more than two years are needed for predators to become accustomed to the treatment and learn to take advantage of it. Another major problem with the habitat alteration was its unnatural appearance. The Refuge quickly removed the experiment with termination of this study. Other forms of habitat alteration such as deferred grazing (Snell and Hlavachick 1980, and Snell 1980) may be more easily applied, more effective, and lack any negative aesthetic properties such as my experiment.

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Rodenticidal Effects of Zinc Phosphide and Strychnine on Nontarget Species[1]

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Abstract.--When three rodenticide treatments--zinc phosphide (prebaited) and strychnine (both with and without prebait)--were evaluated, zinc phosphide was the most effective in reducing active burrows of prairie dogs; but, it also resulted in a reduction in deer mouse densities. One month after treatment, counts of fecal pellets of eastern cottontails were greater on areas treated with strychnine without prebait than on sites treated with zinc phosphide. Eight months after treatment, no differences could be detected among rodenticides for either leporid. Horned lark densities were reduced 61% on sites treated with strychnine only.

INTRODUCTION

Rodenticides have been used for prairie dog control on the Great Plains since the late 1800's (Merriam 1902). Most recent prairie dog control programs on federal, state, and private lands consist of poisoning prairie dogs with zinc phosphide on rolled oats after prebaiting with rolled oats (Schenbeck 1982). However, for more than 70 years, little effort has been made to evaluate rodenticide impacts on nontarget animals. Recently there has been some concern about the effects of zinc phosphide on nontarget animals. Bell and Dimmick (1975) reported that zinc phosphide was not hazardous to red fox (Vulpes fulva), gray fox (Urocyon cinereoargenteus), or great horned owls (Bubo virginianus). Kit fox (Vulpes macrotis) survived after feedings on kangaroo rats (Dipodomys sp.) killed with zinc phosphide (Schitoskey 1975). Matschke et al. (1983) reported no mortality among nontarget animals when zinc phosphide-treated grain bait was broadcast to control Richardson's ground squirrels (Spermophilus richardsonii).

Strychnine, used for prairie dog control since the late 1800's (Merriam 1902), has been reported to present secondary hazards to nontarget animals (Schitoskey 1975, Hegdal et al. 1981). Wood (1965) reported that densities of five rodent species fluctuated independently over a 2-year period after an area was poisoned with strychnine-treated oats. Birds were killed by surface application of steam-rolled oats treated with strychnine for control of Richardson's ground squirrels (Hegdal and Gatz 1977). No detrimental effects were observed on other rodents or mammalian predators.

To augment the limited information, this investigation was undertaken to compare zinc phosphide and strychnine for effects on nontarget small mammals and birds.

STUDY AREA

The study area was approximately 13 km south of Wall on the Buffalo Gap National Grasslands and Badlands National Park in west-central South Dakota. Climate was semiarid-continental and was characterized by cold winters and hot summers. The average annual precipitation, based on climatological information over a 12-year period (1972-1983) from the weather station at Cedar Pass Visitor Center, Badlands National Park, was 40 cm. Most precipitation fell during the growing season as high-intensity thundershowers, which produced a wide range of amounts and intensities of rain for any given location. The mean annual temperature was 10 °C, ranging from -5 °C in January to 26 °C in July.

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[1]Paper presented at the 8th Great Plains Damage Control Workshop. (Rapid City, SD, April 28-30, 1987).

[2]Uresk and King are Research Biologist and Biometrician, respectively, with the Rocky Mountain Forest and Range Experiment Station, Rapid City, S. Dak., in cooperation with the South Dakota School of Mines and Technology; the Station's headquarters is in Fort Collins, in cooperation with Colorado State University. Apa and Deisch were graduate research assistants, and Linder, now retired, formerly Unit Leader, South Dakota Cooperative Fish and Wildlife Research Unit, South Dakota State University, Brookings. Partial funding of this study was provided by National Agricultural Pesticide Impact Assessment Program (NAPIAP).

Soils developed primarily from sedimentary deposits of clay, silt, gravel, and volcanic ash (Raymond and King 1976). Steep gullies, sharp ridges, flat-topped buttes, pinnacles that are partly covered with vegetation, and upland grasslands characterize much of the landscape in the Badlands. Gently sloping grasslands on the National Grasslands made up the major portion of the study area.

The dominant grasses were blue grama (*Bouteloua gracilis*), buffalograss (*Buchloe dactyloides*), needleleaf sedge (*Carex eleocharis*), and western wheatgrass (*Agropyron smithii*). Scarlet globemallow (*Sphaeralcea coccinea*), prostrate bigbract verbena (*Verbena bracteata*), Patagonia Indianwheat (*Plantago patagonica*), and prairie dogweed (*Dyssodia papposa*) were the major forbs.

The Badlands National Park area was grazed by bison (*Bison bison*), pronghorn (*Antilocapra americana*), and mule deer (*Odocoileus hemionus*) throughout the year. Cattle on the National Grasslands grazed the area from mid-May to the last of October each year. Stocking levels varied depending upon moisture and available forage. Pronghorn and mule deer grazed the grasslands throughout the year.

METHODS

Eighteen study sites were established on 15 prairie dog colonies that ranged in area from approximately 12 ha to 283 ha. Nine sites were untreated and 9 sites were treated with the rodenticides zinc phosphide (prebaited) and strychnine, with and without prebaiting; thus, each rodenticide treatment had 3 control and 3 treated sites. The 3 rodenticide treatments were clustered into 3 separate groups in an attempt to minimize the possibility that a nontarget animal would be exposed to more than one rodenticide. Clusters were approximately 13 and 16 km apart. Zinc phosphide treatments were applied to sites in the Badlands National Park because of administration constraints against the use of strychnine in such areas. The other 2 treatment groups, strychnine with and without prebaiting with steam-rolled oats, were assigned randomly to the 2 remaining clusters on the National Grasslands.

Steam-rolled oats from the U.S. Fish and Wildlife Service's Pocatello Supply Depot were used for both prebait and carrier. A 2.0% by weight active zinc phosphide and 1.5% Alcolec S[3] adhesive were applied to the oats. Strychnine alkaloid was applied to the oats as 0.5% by weight. Nontreated oats were applied as prebait for zinc phosphide and for 1 of the strychnine treatments during September 20-21, 1983, on prairie dog colonies (Uresk et al. 1986). Active rodenticides on steam-rolled oats were applied during September 22-24, 1983. These rodenticide treatments resulted in active prairie dog burrows being reduced 95% with zinc phosphide, 83% with strychnine (prebaited), and 45% with strychnine only (Uresk et al. 1986).

Pretreatment counts for small mammals and birds were taken on all sites 1 week before application of rodenticides. Posttreatment sampling on all sites began on the fourth day after rodenticides were applied.

Small rodents were sampled on each of the 18 sites before and after treatment. Sixty-four Sherman live traps (23 x 9 cm) were arranged within a grid design with 10-m spacings on each site. Each trap session consisted of 1 night of prebaiting followed by 4 consecutive nights of trapping. All traps were examined for mammals each morning. Traps closed by prairie dogs through the day were reopened in the late afternoon on all sites. A mixture of peanut butter and rolled oats was used for bait in the batting-lined traps. Heavy wire was placed over each trap and inserted into the ground, to reduce disturbance by weather, large herbivores, and prairie dogs. Captured rodents were identified as to species and assigned a unique number by toe amputation. Relative density estimates were obtained as the number of unique animals captured on each site by trap session.

Fecal pellets were used as an index of abundance for the eastern cottontail (*Sylvilagus floridanus*) and white-tailed jackrabbit (*Lepus townsendii*) on all 18 sites (Overton 1971). Thirty 1-m^2 circular plots, spaced 30 m apart, were permanently established along transects (0.8 km) on each site. Fecal pellets were collected pre- and post-rodenticide treatment 1 month and 8 months following treatment. Data were analyzed as mean number of pellets per site.

Avian populations were counted on the 18 study sites by using a modified transect method (Emlen 1971, 1977; Rotenberry 1982). Eighteen permanent strip transects, 1 per site, 805 m long and 61 m wide (approximately 4.9 ha), were established. Surveys were conducted on 4 consecutive days before and after rodenticide treatment in a different site order each day. Survey teams started one-half hour after sunrise and continued for approximately 4-5 hours; average walking time was 25-40 minutes per transect. All birds within each transect were identified visually or by vocalization, including birds flying through the transect during the census. Data were averaged over the 4 days by species, and mean numbers of birds per site were used in statistical analyses.

STATISTICAL EVALUATION

The approach chosen to assess the effect of each rodenticide was to compare the change between pretreatment and posttreatment observations on each

[3]The use of the name Alcolec S (American Lecithin Co., Inc.) is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

treated group (cluster) of sites with the change observed on the respective control sites. When a significant correlation existed between pretreatment and posttreatment observations, analysis of covariance was used to estimate change as the posttreatment observation adjusted for the amount by which the pretreatment observation differed from the pretreatment mean. That is,

$$Z_{ij} = Y_{ij} - b(X_{ij} - X)$$

where Z_{ij} is the adjusted observation for the j-th site in the i-th treatment group, Y_{ij} is the posttreatment observation, X_{ij} is the pretreatment observation, X is the mean of pretreatment observations, and b is the regression coefficient. If correlation between pretreatment and posttreatment observations was nonsignificant, change was estimated simply as

$$Z_{ij} = Y_{ij} - X_{ij}$$

and the analysis was based on an interaction between time and treatment as the indicator of a significant change due to treatment (Green 1979). Unless indicated otherwise, the statistical package for the social sciences (SPSS) was used to produce the statistical calculations (Nie et al. 1975, Hull and Nie 1981).

Once the form of the change variable (Z_{ij}) was chosen, contrasts between treated and respective control groups were formed as $C_1 = Z_1 - Z_2$, $C_2 = Z_3 - Z_4$, and $C_3 = Z_5 - Z_6$, where Z_1 represents the estimated average change on the zinc phosphide sites, Z_2 the estimated average change on the respective control sites, and so on for the prebaited strychnine and strychnine only treatments. If significant individual treatments effects were observed, comparisons among the rodenticides were produced by forming the contrasts $C_4 = C_1 - C_2$, $C_5 = C_1 - C_3$, and $C_6 = C_2 - C_3$.

Randomization procedures were used to estimate the statistical significance of the various contrasts (Edgington 1980, Romesburg 1981). These procedures do not rely on the normality assumption inherent in standard analysis of variance testing techniques; rather, they provide a general framework incorporating separate but similar analyses depending on the outcome of tests for significant correlation between pretreatment and posttreatment observations, common regression slopes among treatment groups, and homogeneous variance among treatment groups. A test statistic, $t = C_i/\text{Sqrt}[\text{Var } C_i]$, was computed for each contrast (C_i) and significance level estimated using randomization procedures based on 10,000 random permutations of the data pairs (X_{ij}, Y_{ij}) among the treatment groups. Variance of a contrast was computed as the sum of the variances of the means in the contrast, with individual variances computed based on the covariance and homogeneous variance assumptions appropriate for the particular variable.

Because omission of any effect due to poisoning, especially for the nontarget species, was considered more serious than the potential incorrect declaration of a significant treatment effect, Type II error protection was produced by testing each contrast individually. However, except when heterogeneous variance was present and therefore no overall test was available, some Type I error protection was afforded by testing individual contrasts only after first observing a significant (P = 0.10) overall test of treatment differences using analysis of variance or covariance (Carmer and Swanson 1973). Individual contrasts were considered biologically significant at P = 0.25. Although admittedly unconventional, for the number of sites available for study, this significance criterion produces a power (probability of detecting a true difference) of approximately 0.75 for a contrast twice as large as its standard error. This was considered a reasonable combination of Type I and Type II error protection for this study (Carmer 1976, Salsburg 1985).

RESULTS

Small Rodents

Six rodent species were captured on the 18 sites: deer mouse (Peromyscus maniculatus), northern grasshopper mouse (Onychomys leucogaster), thirteen-lined ground squirrel (Spermophilus tridecemlineatus), western harvest mouse (Reithrodontomys megalotis), Ords kangaroo rat (Dipodomys ordii), and hispid pocket mouse (Perognathus hispidus). Deer mice were the only rodent captured in sufficient numbers to be used for statistical comparisons; however, no significant reductions (P = 0.363) were observed among treatments. Relative densities of deer mice changed 79% from 5.8 to 1.2 unique animals, following the zinc phosphide treatment (table 1).

Leporids

No differences were found in the adjusted fecal pellet means of the eastern cottontail between control and treated sites for zinc phosphide and strychnine without prebait (P = 0.812 and P = 0.655, respectively, table 2). Areas treated with strychnine (prebait) showed an increase (P = 0.031) in adjusted mean number of fecal pellets. However, no differences were found between treated and control sites for fecal densities 8 months after prairie dogs had been poisoned (table 2).

Higher numbers of fecal pellets of white-tailed jackrabbits were observed (P = 0.088) on the zinc phosphide sites versus control (table 3). No differences in jackrabbit abundance were found between control and treated sites on areas treated with strychnine with (P = 0.725) and without prebaiting (P = 0.683). However, 8 months after rodenticides were applied, whitetail jackrabbit fecal pellet counts were not different between treated and control sites (P = 0.431).

Birds

Application of zinc phosphide for black-tailed prairie dog control did not significantly reduce

Table 1.--Relative densities of deer mice (unique animals/768 trap nights ± standard error) for pretreatment and posttreatment on treated and control sites for each rodenticide. Variances were heterogeneous and pretreatment data were used to adjust posttreatment means by covariance analysis. Adjusted posttreatment data had homogeneous variances.

Treatment	Pretreatment	Posttreatment	Adjusted effect[1]
Prebait: Zinc phosphide			
Treated	8.3 ± 2.6	1.3 ± 0.7	
Control	4.0 ± 2.0	2.3 ± 0.9	-4.6 ± 2.7
Strychnine			
Treated	1.9 ± 1.0	0.7 ± 0.7	
Control	9.0 ± 3.2	7.0 ± 4.0	0.3 ± 2.7
Prebait: Strychnine			
Treated	8.7 ± 1.5	3.7 ± 1.9	
Control	18.0 ± 3.1	12.3 ± 4.9	-0.9 ± 2.7

[1]Adjusted effects were not significant ($P = 0.363$); therefore, statistical significance of contrasts was not determined.

Table 2.--Average pellet counts (mean/30 m^2 ± standard error) of eastern cottontail for pretreatment and posttreatment on treated and control sites for each rodenticide. Variances were homogeneous and pretreatment data were used as covariate to adjust posttreatment means.

Treatment	Pretreatment	Posttreatment	Adjusted effect[1]	Significance level (control vs. treated)[1]	Adjusted effect 8 mo. after treatment[2]
Prebait:Zinc phosphide					
Treated	17 ± 6	8 ± 7			
Control	158 ± 133	32 ± 30	3.9 ± 13.1[1]	0.812	-4.6 ± 13.9
Strychnine					
Treated	31 ± 13	16 ± 15			
Control	183 ± 109	54 ± 19	-7.5 ± 13.1	0.655	20.2 ± 13.9
Prebait:Strychnine					
Treated	102 ± 22	25 ± 14			
Control	296 ± 97	30 ± 16	34.0 ± 13.4	0.031	15.1 ± 13.9

[1]Randomization test used for testing differences between pairs of adjusted means.
[2]Adjusted effects were not significant ($P = 0.260$); therefore, statistical significance of contrasts was not evaluated.

Table 3.--Average pellet counts (mean/30 m^2 ± standard error) of white-tailed jackrabbits for pretreatment and posttreatment on treated and control sites for each rodenticide.

Treatment	Pretreatment	Posttreatment	Adjusted effect[1]	Significance level (control vs. treated)[2]	Adjusted effect 8 mo. after treatment[3]
Prebait:Zinc phosphide					
Treated	9 ± 7	43 ± 31			
Control	72 ± 40	16 ± 12	90.4 ± 46.3	0.088	70.0 ± 41.6
Strychnine					
Treated	11 ± 2	5 ± 2			
Control	24 ± 18	22 ± 12	-5.0 ± 9.0	0.683	18.7 ± 41.6
Prebait:Strychnine					
Treated	34 ± 24	42 ± 17			
Control	69 ± 58	49 ± 8	28.0 ± 60.1	0.725	37.7 ± 41.6

[1]Posttreatment minus pretreatment was used to adjust data since covariance model was not significant ($P = 0.502$) and variances were heterogeneous.
[2]Randomization test used for testing differences between pairs of adjusted means.
[3]Posttreatment minus pretreatment was used to adjust data since covariance model was not significant ($P = 0.450$). Adjusted effects were not significant ($P = 0.431$); therefore, statistical significance of contrasts was not evaluated.

numbers of horned lark (Eremophilia alpestris) ($P = 0.974$, table 4). When strychnine was applied without prebait, horned larks were significantly reduced ($P = 0.114$). Strychnine with prebaiting also had apparent effects on horned lark densities ($P = 0.124$). Comparisons among rodenticides showed no differences with zinc phosphide compared to strychnine only and strychnine with prebait, $P = 0.256$ and $P = 0.267$, respectively. Strychnine comparisons were not different ($P = 0.964$).

Because individual bird species densities were highly variable, 15 species of birds were grouped to determine treatment effects among rodenticides (table 5). Overall test among treatments was significant ($P = 0.025$). Ground feeding birds showed no differences between control and treated sites in adjusted relative densities on zinc phosphide ($P = 0.431$), prebaited strychnine ($P = 0.360$), and strychnine ($P = 0.364$) treatment areas. A comparison among rodenticides showed differences between zinc phosphide with strychnine ($P = 0.228$), and zinc phosphide with prebait strychnine ($P = 0.223$). Higher densities of birds were observed on the zinc phosphide-treated sites.

DISCUSSIONS AND CONCLUSIONS

Zinc phosphide as a prairie dog control agent, was associated with reduced densities (79%) of deer mouse, a nontarget species; however, the effect was

Table 4.--Relative densities of horned lark (mean number/4.9 ha ± standard error) for pretreatment and posttreatment on treated and control sites for each rodenticide. Pretreatment data were different ($P = 0.043$) among rodenticides, and analysis was conducted on posttreatment minus pretreatment data.

Treatment	Pretreatment	Posttreatment	Adjusted effect	Significance level (control vs. treated)[1]
Prebait: Zinc phosphide				
Treated	17 ± 6	22 ± 7		
Control	12 ± 5	21 ± 8	0.3 ± 9.3	0.974
Strychnine				
Treated	12 ± 9	2 ± 1		
Control	22 ± 12	17 ± 8	-15.2 ± 9.3	0.114
Prebait: Strychnine				
Treated	30 ± 8	6 ± 3		
Control	67 ± 20	20 ± 2	-14.6 ± 9.3	0.124

[1]Randomization test used for testing differences between pairs of adjusted means.

Table 5.--Relative densities of total ground-feeding birds (mean number/4.9 ha ± standard error) for pretreatment and posttreatment on treated and control site for each rodenticide. Correlation was not significant ($P = 0.248$). Analysis was conducted on posttreatment minus pretreatment data.[1]

Treatment	Pretreatment	Posttreatment	Adjusted effect	Significance level (control vs. treated)[2]
Prebait: Zinc phosphide				
Treated	31 ± 6	53 ± 12		
Control	24 ± 8	38 ± 16	15.0 ± 12.9	0.431
Strychnine				
Treated	18 ± 12	4 ± 2		
Control	25 ± 13	20 ± 10	-16.9 ± 12.9	0.364
Prebait: Strychnine				
Treated	31 ± 8	7 ± 2		
Control	72 ± 18	24 ± 4	-17.2 ± 12.9	0.360

[1]Avian species that showed no differences individually or grouped: Sharp-tailed Grouse (Tympanuchus phasianellus), Killdeer (Charadrius vociferus), Mourning Dove (Zenaida macroura), Northern Flicker (Colaptes auratus), Says Phoebe (Sayornis phoebe), Black-billed Magpie (Pica pica), American Crow (Corvus brachyrhynchos), Mountain Bluebird (Sialia currucoides), American Robin (Turdus migratorius), Water Pipit (Anthus spinoletta) migrant, European Starling (Sturnus vulgaris), Vesper Sparrow (Pooecetes gramineus), Savannah Sparrow (Passerculus sandwichensis), Chestnut-collared Longspur (Calcarius ornatus), Western Meadowlark (Sturnella neglecta).

[2]Randomization test used for testing differences between pairs of adjusted means.

not statistically significant because of high variability in densities. Strychnine with or without prebait was not associated with significant reductions in deer mouse densities. This finding is contrary to the 86% reduction in rodent populations reported by Wood (1965) 1 month after treatment with strychnine.

Pellet counts have been used to measure relative abundance of rabbit numbers in various habitats (Vorhies and Taylor 1933; Arnold and Reynolds 1943; Westoby and Wagner 1973; MacCracken and Hansen 1982). Conde (1982) compared the abundance of pygmy rabbits (Sylvilagus idahoensis) and black-tailed jackrabbits (Lepus californicus) by strip census with fecal pellet counts and showed a good correlation between the 2 methods. In this study, eastern cottontail fecal pellet counts after treatment were greater on strychnine-prebaited sites than on other treated sites. This may be attributable to the slightly rougher terrain of the strychnine area, offering a more suitable habitat for cottontails (Flinders and Hansen 1975). However, 8 months after treatment in this study, eastern cottontails showed no differences among rodenticide treatments. White-tailed jackrabbit abundance was higher on areas treated with zinc phosphide immediately after treatment. This flat and open area is preferred by the white-tailed jackrabbits. In addition, western wheatgrass, a major food item of white-tailed jackrabbits, was more abundant on zinc phosphide sites compared to the other rodenticide-treated areas (Flinders 1971). Eight months later, in our study, white-tailed jackrabbit abundance was not different among rodenticide treatments. The 3 rodenticides did not negatively affect either eastern cottontails or white-tailed jackrabbits.

Effect of strychnine on some bird species has been documented by several investigators. Rudd and Genelly (1956) stated that hazards of strychnine application in the field were much higher for waterfowl than for upland game birds such as Gray partridge (Perdix perdix), ring-necked pheasant (Phasianus colchicus), quail (Odontophorinae), sharp-tailed grouse (Tympanuchus phasianellus), and prairie chicken (Tympanuchus sp.). Hegdal and Gatz (1977) reported that there was a significant hazard to some seed-eating birds, which included horned larks, mourning doves (Zenaida macroura), and blackbirds (Emberizinae). They also stated that vesper sparrows (Pooecetes gramineus) and western meadowlarks (Sturnella neglecta) were affected but to a lesser extent. Tietjen (1976) and Matschke et al. (1983) reported no significant mortality for nontarget seed-eating birds with application of zinc phosphide, but additional tests were recommended.

Horned larks in this study decreased in relative density on areas treated with strychnine and prebait strychnine. However, zinc phosphide showed no effects. The time of rodenticide application during the fall could have influenced the number and species of birds affected. Weather conditions can affect the movements of migrant birds as well as resident birds during the time when rodenticides are applied. Ground-feeding birds individually or as a group excluding horned larks showed no response to the 3 rodenticide treatments. Many of the ground-feeding birds were beginning to group in certain areas because of inclement weather during post-treatment measurements. This increased variability between and among sites may have contributed to the lack of significant effects of rodenticide treatment for ground-feeding birds as a group. A comparison of rodenticides showed greater effects on birds with both strychnine treatments and less with zinc phosphide.

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Efficacy of Aluminum Phosphide for Black-Tailed Prairie Dog and Yellow-Faced Pocket Gopher Control[1]

P. Rodger Moline and Stephen Demarais[2]

Abstract. The efficacy of aluminum phosphide was tested on a total of 300 active black-tailed prairie dog (Cynomys ludovicianus) mounds and 68 active yellow-faced pocket gopher (Pappogeomys castanops) tunnels during June-August, 1986 on the southern Great Plains in Lubbock County, Texas. Efficacy of aluminum phosphide was higher than controls ($P < 0.001$) for both species. Efficacy was higher for black-tailed prairie dogs (94.7 - 96.0%) than for pocket gophers (61.5 - 85.7%). Soil porosity and moisture appeared to influence efficacy for yellow-faced pocket gophers.

INTRODUCTION

Black-tailed prairie dogs (Cynomys ludovicianus) and yellow-faced pocket gophers (Pappogeomys castanops) can be nuisances to ranchers, farmers, and urban dwellers on the southern Great Plains. However, in spite of the significant effects prairie dogs have on forage availability (Hansen and Gold 1977), short-term benefits of prairie dog control to cattle grazing may be limited (Klait and Hein 1978). Based on animal unit gains, control of prairie dogs in South Dakota using toxic bait may not be economically feasible (Collins et al. 1984).

Additional justification for control of prairie dogs and/or pocket gophers involves public health (Collins et al. 1984) and damage to agricultural crops (Chase et al. 1982), urban gardens, and landscapes. Pocket gophers can cover up to one-fourth of the ground surface with mounds and castings in one year (Turner 1973).

Aluminum phosphide is a commercially available burrow fumigant (Phostoxin, Degeshe Co., Inc.)[3] that emits hydrogen phosphide gas. Initial field tests of aluminum phosphide for control of black-tailed prairie dogs in Kansas indicated an efficacy of 80%[4]. The efficacy of aluminum phosphide for control of yellow-faced pocket gophers has not been reported. We evaluated the efficacy of aluminum phosphide for control of black-tailed prairie dogs and yellow-faced pocket gophers on the southern Great Plains.

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METHODS

The study was conducted during June - August, 1986, on 80 ha of the Texas Boys Ranch, located approximately 10 km northeast of Lubbock, Lubbock County, Texas. The shortgrass prairie vegetation on the study area is dominated by blue grama (Bouteloua gracilis) and buffalograss (Buchloe dactyloides). Mean annual precipitation is 46 cm (Blackstock 1979). The study area was grazed by cattle until 3 months before treatment.

Two trials were conducted for each species, with a treatment area and a control area assigned randomly within each trial. Two trials were conducted during June 1986 on one contiguous black-tailed prairie dog colony that was arbitrarily delineated into 4 20-ha sampling units. One trial on yellow-faced pocket gophers was conducted on arbitrarily delineated control and treatment areas during June, 1986. The second trial on yellow-faced pocket gophers consisted

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[1] Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop, Rapid City, S. D., April 28-30, 1987.

[2] P. Rodger Moline and Stephen Demarais are Graduate Research Assistant and Research Scientist, respectively, in the Range and Wildlife Management Department, Texas Tech University, Lubbock.

[3] Reference to trade name does not imply endorsement.

[4] Boggess, E. K. 1979, Aluminum phosphide for prairie dog control. Unpublished report. Kansas State University, Cooperative Extension Service, Garden City.

of 2 separate control and treatment populations sampled during August, 1986.

The trials on black-tailed prairie dogs and the first trial on yellow-faced pocket gophers were located in Estacado clay loam, a friable, moderately alkaline, dark brown clay loam 36 cm thick. The second trial on yellow-faced pocket gophers was located in Midessa fine sandy loam, a friable, moderately alkaline, brown sandy loam about 18 cm thick.

Six uniformly located soil samples were collected within each trial site at a depth of 45 cm. Soil moisture and porosity were calculated because these variables affect gas diffusion (McClean 1981) and may affect efficacy of a fumigant such as aluminum phosphide. Soil moisture and porosity were estimated using drying oven and water displacement techniques, respectively.

Occupancy of each burrow was established prior to sampling. All prairie dog mounds in each sampling unit were filled with soil and numbered. Pocket gopher tunnels were opened and numbered. Attempts were made to open only one tunnel per pocket gopher burrow system. A pocket gopher tunnel was considered discrete from other burrow systems if it was in an area with fresh mounds and/or earth plugs (Reid et al. 1966) which was spatially separated from other similar areas of activity. Occupancy of mounds and tunnels was determined 2 days later by checking for opening and closure, respectively.

Active burrows were treated with 2 3-gram pellets of aluminum phosphide. The openings of all active prairie dog mounds were plugged with plastic trash bags containing 5-10 kg of soil. The plastic-bag plug was covered with loose soil. One pocket gopher tunnel opening in each burrow system was plugged with loose soil piled onto a cardboard plug.

Seven days after treatment all burrows were checked for activity using the same methods used to determine pretreatment occupancy. Efficacy was calculated using the following formula: Efficacy = 100 x [(No. of Pretreatment Active Burrows - No. of Posttreatment Active Burrows) - No. of Pretreatment Active Burrows]. Efficacy was compared between aluminum phosphide treatment and control within each trial using a chi-square test.

RESULTS AND DISCUSSION

Three hundred black-tailed prairie dog mounds and 68 yellow-faced pocket gopher tunnels were sampled. Efficacy of aluminum phosphide treatment was higher than controls (P 0.001) for both species (Table 1). Efficacy was higher for prairie dogs (94.7-96.0%) than for pocket gophers (61.5-85.7%).

Although toxic gases have been used for vertebrate pest control for many years, there is relatively little efficacy data available from controlled experiments (Elias et al. 1983). Our 94.7-96.0% efficacy results exceed the 80% control of black-tailed prairie dogs using aluminum phosphide in dry soils in Kansas[4] The Kansas results were only an approximation because burrows were not tested for activity prior to treatment. We found no reports on control of yellow-faced pocket gophers using aluminum phosphide, but results exceeded Miller's (1954) generalization that best control of "gophers" with "gases" ranges from 50-60%.

Table 1. Results of application of aluminum phosphide to active black-tailed prairie dog mounds and yellow-faced pocket gopher tunnels in the southern Great Plains, June-August, 1986.

Species	Active Pre-treatment N	Active Post-treatment N	Efficacy[a] %
Black-tailed Prairie Dogs			
Treatment A[b]	75	3	96.0
Treatment B[b]	75	4	94.7
Control A	75	69	8.0
Control B	75	65	13.3
Yellow-faced Pocket Gophers			
Treatment A[b]	21	3	85.7
Treatment B[b]	13	5	61.5
Control A	21	21	0.0
Control B	13	13	0.0

[a] See text.
[b] Efficacy of treatment higher than respective control ($P < 0.001$).

Various biological and chemical controls have been used against prairie dogs and pocket gophers. Grazing deferment reduced prairie dog populations in Kansas (Snell and Hlavachick 1980) and South Dakota (Uresk et al. 1982). Opinions vary as to the impact coyotes have on pocket gopher and prairie dog populations (Snell and Hlavachick 1980, Baroch and Poche 1985). Herbicide treatment reduced forbs and resulted in an 87% decline in northern pocket gopher (Thomomys talpoides) populations 1 year after treatment (Keith et al. 1959). Herbicide treatment failed to reduce black-tailed prairie dog populations in Montana because the animals switched from a diet of forbs to grasses (Fagerstone et al. 1977). Toxic baits can be up to 100% effective in controlling pocket gophers (Baroch and Poche 1985) but may not be economically feasible (Collins et al. 1984).

Soil moisture and porosity may affect the efficacy of burrow fumigants (McClean 1981). Diffusion rate, the main factor influencing spread of aluminum phosphide gas through rabbit burrows (Oliver and Blackshaw 1979), is related to both soil moisture and porosity. Increased soil moisture would positively affect the rate of aluminum phosphide diffusion and thus its efficacy by increasing the rate of gas generation (Oliver and Blackshaw 1979) and

reducing the amount of air-filled pore space (McClean 1981). A greater relative loss of gas into the surrounding pore spaces, resulting in decreased efficacy, would be expected in soils with greater porosity. The efficacy of aluminum phosphide was lower in the second trial on yellow-faced pocket gophers (Table 1). The positive impact of higher soil moisture apparently was negated by the greater soil porosity in the second trial (Table 2).

Our results indicate that aluminum phosphide is a highly effective burrow fumigant for black-tailed prairie dogs and yellow-faced pocket gophers. Additional research is needed concerning the effect of soil moisture and porosity on efficacy. The cost effectiveness of aluminum phosphide control of burrowing rodents needs to be evaluated relative to other management alternatives, particularly in urban environments.

Table 2. Soil porosity (%) and moisture (%) at 45 cm depth at the time of treatment with aluminum phosphide.

Species	N	Porosity $\bar{X} \pm SE$	Moisture $\bar{X} \pm SE$
Black-tailed Prairie Dogs			
Treatment A	3	49.1 ± 0.5	3.3 ± 0.2
Treatment B	3	48.5 ± 0.5	4.5 ± 0.9
Control A	3	47.2 ± 1.0	4.1 ± 0.4
Control B	3	48.2 ± 1.7	4.7 ± 0.5
Yellow-faced Pocket Gophers			
Treatment A	3	49.1 ± 0.5	3.3 ± 0.2
Treatment B	3[a]	63.7 ± 0.3	22.2 ± 2.0
Control A	3	47.2 ± 1.0	4.1 ± 0.4
Control B	3[a]	63.7 ± 0.3	22.2 ± 2.0

[a]Data for treatment B and Control B represent 3 samples collected randomly over both areas.

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Laboratory Trial of Chlorophacinone As a Prairie Dog Toxicant[1]

Daryl D. Fisher[2] and Robert M. Timm[3]

Abstract.--A laboratory trial was conducted to investigate the efficacy and secondary toxicity of chlorophacinone oats as a prairie dog toxicant. Bait containing 0.0025% chlorophacinone killed 29 of 31 prairie dogs when offered in 25 gram amounts daily for 6 days. Five of 6 domestic ferrets died of anticoagulant poisoning when fed 4 of these toxicant-killed prairie dogs over 8 days. Chlorophacinone may not be an acceptable prairie dog toxicant due to this potential secondary hazard.

INTRODUCTION

In numerous places throughout their range, black-tailed prairie dog (*Cynomys ludovicianus*) populations have been increasing in recent years. While these increases may have multiple causes, some authorities point to increased restrictions on the use of toxicants, including the 1972 Presidential Executive Order which limited toxicant use on public lands (Fagerstone 1982). In western Nebraska, prairie dog populations may have increased as much as 60% from 1970 to 1980 (Nebraska Game and Parks, unpubl. data).

Prairie dogs' feeding activities can alter the vegetative composition of rangeland plant communities, resulting in reduced forage productivity (Hansen and Gold 1977). While it is generally believed that prairie dogs and livestock can compete for forage, the amount of competition may vary from site to site (Fagerstone 1982) and from year to year. There are few studies that document the economic impact of these rodents on rangeland.

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[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop [Rapid City, S.D., April 28-30, 1987].

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Despite the absence of such economic assessments, many landowners believe prairie dog control to be desirable. The most cost-effective and practical method of rapidly reducing prairie dog populations is by application of toxic grain bait. Zinc phosphide and strychnine are the only active ingredients presently used in federally registered prairie dog baits (Jacobs 1983). Two fumigants, aluminum phosphide and gas cartridges, are currently available for burrow fumigation. The higher cost and relatively non-selective action of fumigants makes them a viable control option only on small areas or as a follow-up to toxic grain bait treatment.

The efficacy of strychnine and zinc phosphide baits is variable and often control results are not as successful as desired (Holbrook and Timm 1985). Poor success of toxicant use against prairie dogs often results from such causes as failure to prebait, alternate food resources, weather changes during bait application, and repeated use of toxicants on bait-shy populations. Further, concerns have been raised about the potential hazard of currently-registered toxicants to non-target species, particularly the endangered black-footed ferret (*Mustela nigripes*). Clearly, alternative prairie dog toxicants are needed.

The purpose of this study was to investigate, in the laboratory, the potential of the anticoagulant chlorophacinone as a prairie dog toxicant. We wanted to find an appropriate bait concentration, determine its effectiveness against prairie dogs, and investigate its secondary toxicity.

BAIT FORMULATION

We live-trapped wild black-tailed prairie dogs from Morrill County, Nebraska. They were weighed, dusted with the insecticide Sevin, and housed in individual metal cages. We fed them Wayne Rodent Blox (Wayne Pet Food Division, Continental Grain Co., Chicago, Ill.) ad lib. and gave them watermelon or sugar beet slices as a source of moisture. We offered the animals untreated crimped oats daily while we acclimated them to the laboratory. Only animals which accepted oats were used in subsequent trials.

To determine the lowest effective bait concentration, we formulated chlorophacinone at three concentrations, 0.01%, 0.005%, and 0.0025% active ingredient (a.i.). Two percent chlorophacinone concentrate (RoZol Dry Concentrate, Chempar Products, New York) was suspended in corn oil and the solution mixed with crimped oats, by hand, until it appeared to be mixed evenly.

Twenty-four prairie dogs which had readily consumed untreated oats were randomly assigned, eight to each of the 3 bait formulations. Twenty-five grams of the respective bait formulation was offered to each prairie dog daily, for 6 consecutive days. The amount of treated oats remaining was recorded daily for each animal. The laboratory chow was not available during the 6 day baiting, while the water source continued to be offered. Following the six days of baiting, the prairie dogs were returned to their laboratory rodent chow and water source diet. They were observed for 21 days or until death occurred. Carcasses of all anticoagulant-killed prairie dogs were frozen upon death. The identity of each prairie dog was maintained throughout the trial.

Each of the bait formulations tested caused total mortality of the test animals. The lowest concentration (0.0025% a.i.) was chosen for further evaluation. Additional dosed prairie dogs were needed to provide sufficient numbers of poisoned prairie dogs for testing of secondary toxicity. Twenty-three additional prairie dogs were offered the 0.0025% bait concentration, following the same procedure as outlined above. Twenty-one prairie dogs died of anticoagulant poisoning while 2 survived beyond the 21-day observation period. The animals which died as a result of the 0.0025% treatment had consumed dosages between 1.3 and 5.5 mg/kg. Of the surviving animals, one consumed relatively little of the treated oats (0.4 mg/kg), while the other consumed a greater quantity than did 17 other test animals which subsequently died.

SECONDARY TOXICITY

Any toxicant that is to be newly registered for prairie dog control will necessarily undergo detailed scrutiny concerning potential non-target hazards. The potential presence of the endangered black-footed ferrets in prairie dog towns underscores this concern. We chose domestic ferrets (*Mustela putorius*) as surrogate test animals for our secondary toxicity evaluation.

Eight domestic ferrets, 4 of each sex, were housed individually in metal cages. Purina Cat Chow and water were available ad lib. during acclimation to the laboratory.

One male and one female ferret were randomly chosen to serve as controls. All ferrets were given 3 thawed, untreated prairie dog carcasses, one every other day, to condition them to eating prairie dogs. In order to more quickly induce feeding behavior, we had to partially skin the rodent carcasses. The skin on the thawed prairie dogs was sliced along the belly, and peeled off one side, to expose underlying tissue, taking care not to cut into the abdominal cavity. This procedure was followed on all subsequent prairie dog carcasses offered to all ferrets.

Following this conditioning regime, we gave each treatment ferret 4 prairie dog carcasses poisoned with 0.0025% chlorophacinone bait, one every other day, while the control ferrets received 4 unpoisoned carcasses. The consumed portions of each treated prairie dog were noted as it was removed from the ferret cage. The Cat Chow diet was not available to the ferrets during the period when prairie dog carcasses were offered.

The ferrets were returned to the Cat Chow diet following removal of the last treated prairie dog. Ferrets were then observed for 30 days, or until death occurred. Five of the 6 treatment ferrets died of anticoagulant poisoning, as verified by veterinary necropsy. Internal hemorrhaging was found in the neck and thoracic region in each of the poison-killed ferrets. We observed that all ferrets fed on internal organs as well as muscle tissues of the prairie dogs during the treatment phase. Toxicological analyses of ferret and prairie dog tissues are being conducted, and these results will be published elsewhere.

DISCUSSION

Chlorophacinone-treated oats were found to be an effective prairie dog toxicant at 0.0025% a.i., a concentration lower than that in chlorophacinone baits currently registered for use against pocket gophers and commensal rodents. From this standpoint, it would appear that this compound could provide a useful alternative to strychnine and zinc phosphide. Bait shyness should not be a problem when using an anticoagulant, and there should be no need to prebait. However, more than one field application may be necessary to insure that sufficient bait would be present to be eaten over a number of days. Alternatively, the bait could be made available in weather-resistant bait stations, which would be advantageous especially when attempting to prevent prairie dog town expansion at town perimeters or across property lines.

The secondary toxicity of chlorophacinone to domestic ferrets consuming poisoned prairie dogs, at the dosages we tested, indicates that this compound may not be acceptable. On the basis of our study, we believe it would be unwise to use chlorophacinone baits at these dosages against prairie dogs, unless black-footed ferrets are proven absent from the treatment area and it can be demonstrated that potential secondary toxicity poses no significant hazard to other non-target populations.

We do not automatically conclude, however, that all anticoagulants are unsuitable as prairie dog toxicants because of potential secondary hazard. Other compounds may be metabolized differently by prairie dogs and may be of differing toxicity to non-target species. We believe that because of their potential value in cost-effective control, other anticoagulants should be evaluated for prairie dog control.

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Relevant Characteristics of Zinc Phosphide As a Rodenticide[1]

Rex E. Marsh[2]

Abstract.--Zinc phosphide has a long history of use and remains an important rodenticide for both commensal and select field rodents. A long list of significant characteristics contributes to its relative safety to nontarget species. It is zinc phosphide's relative safeness to humans, most livestock, and nontarget wildlife that has kept it in vogue. A most relevant and highly proclaimed characteristic is its general lack of potential secondary hazard to predators and scavengers. Poor or inconsistent efficacy on certain field rodents is a major shortcoming that can, in part, be compensated for by prebaiting. Zinc phosphide's favorable characteristics support its continued use, and its future prospects appear good.

INTRODUCTION

Zinc phosphide has a relatively long history of use as a rodenticide, and over time its characteristics concerning efficacy, safety and hazards, and environmental associations have been observed and studied. Zinc phosphide has many good characteristics and is widely used for rodent control around the world. Much of its popularity is due to its relatively low cost, although its efficacy is often not as high as is desirable. Its favorable characteristics generally outweigh its shortcomings.

Zinc phosphide was thought to have been first synthesized by Marggraf in 1740 (Wood and LaWall 1926). It was first used as a rodenticide in 1911 to control field rodents in Italy and later in other European countries (Chitty 1954, Freeman et al. 1954, Schoof 1970). Zinc phosphide's use became more extensive during and following World War II.

EARLY USE

Although mentioned in our literature as early as 1935, it appears not to have been used in the United States much before 1939-40 (Munch et al. 1936, Garlough 1941, Schoof 1970). Its use expanded during World War II when thallium sulfate and imported rodenticides like strychnine and red squill were difficult to obtain in adequate quantities. In this country zinc phosphide was first used for the control of commensal rats and mice and shortly thereafter was explored for field rodents.

In 1942 Joseph Keyes evaluated zinc phosphide in extensive field studies involving 58 tons of squirrel bait used in a 5-county area of California (Kalmbach 1942). In May 1942 Doty (1945) commenced studies of its use for the control of rats in the sugarcane fields of Hawaii. It was also early evaluated for vole control in eastern apple orchards.

IMPORTANT CHARACTERISTICS

Zinc phosphide has many good characteristics that sustain its continued use. Many of these are highly relevant to field rodent control as well as commensal rodent control. The following are the most significant of the favorable characteristics:

1. A broad-spectrum rodenticide.
2. Reasonably economical.
3. Relatively safe to humans.
4. Versatile for bait formulations.
5. Relatively slow acting.
6. Reasonably well accepted by many, but not all, target species.
7. No genetic resistance has developed.
8. No acquired tolerance develops.
9. Selectivity protects some nontarget species.
10. Potential secondary hazards are minimal.
11. Can be used in a manner that minimizes hazards to most nontarget species.

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12. Not accumulative in animal tissues to any degree.
13. Detoxifies in the primary target animal carcass over time.
14. Decomposes in the bait form and in the environment, reducing long-term potential hazard and contamination.
15. Translocation in plants minimal or nonexistent.
16. Residue tolerances are established for some crops.
17. Adequately stable when stored under dry conditions (i.e., good shelf-life).
18. Only moderately toxic on an mg/kg basis when compared to some other rodenticides.
19. Generally a good past safety record.

CURRENT USES

In the United States zinc phosphide is used for the control of commensal rodents (house mice, Norway and roof rats), but its use is relatively limited according to most estimates, as anticoagulant rodenticides make up 95% of the baits used for these species.

In agriculture, zinc phosphide finds much greater use for field rodent control, especially for control of rats (Rattus spp.), voles, ground squirrels, prairie dogs, and cotton rats. To a lesser extent it is used for woodrats, pocket gophers, nutria, muskrats, and moles. It has also been evaluated on jackrabbits.

Many, like myself, are not overjoyed by zinc phosphide's effectiveness, at least for some species; however, because of its other good characteristics, it is often used when other rodenticides are inappropriate for some reason or where alternatives are unavailable.

SPECIES SUSCEPTIBILITY

Zinc phosphide is considered a broad-spectrum rodenticide and is used worldwide to control a wide number of native and introduced pest rodent species. LD_{50} values exist for some 22 rodent species; however, it is used for a far greater number of pest rodent species than is suggested by the published LD_{50} values. For the most part, the LD_{50} values for rodents fall between 10 and 40 mg/kg. The nutria has been found the most susceptible of the pest rodent species (LD_{50} 5.6) (Hood 1972). Voles, genus Microtus, are also quite sensitive to zinc phosphide with LD_{50} values for four separate species ranging from 12.4 to 18.0 mg/kg.

The desert kit fox (Vulpes macrotis arsipus) has an LD_{50} of 93 mg/kg, and the introduced mongoose (Herpestes auropunctatus) in Hawaii has an LD_{50} of 82 mg/kg (Keith et al. 1987), indicating that neither of these species is very sensitive to zinc phosphide. It is generally thought that mammalian predators are not very susceptible to zinc phosphide, and this in part is due to its emetic action. However, there are few precise LD_{50} values established for this group of animals.

Several avian species, particularly geese, are very susceptible in the range of 7.5 to 12.0 mg/kg, but most other bird species tested are less susceptible. Caution is advised when making generalizations concerning susceptibility, as considerable variation between species exists--even closely related species.

BAIT TYPES

The versatility of zinc phosphide as a rodenticide is evident by the type of bait formulations and grooming toxicants that are prepared. Whole or crimped grain baits are generally used for voles, ground squirrels, prairie dogs, and rats in agricultural situations, although cereal-based pelleted baits are marketed for the same purposes. Various meal and pelleted baits are used for the control of commensal rodents. Zinc phosphide is sometimes used in grains and incorporated with melted paraffin to form moisture-resistant solid bait blocks, and weather-resistant pelleted baits of other types are also marketed. Chunk or bait cakes are another form of solid baits used in Pakistan (Smythe and Khan 1980).

Perishable baits of fresh fruit, such as apples, oranges, and bananas, and vegetables, including tomatoes, sweet potatoes, cabbage, corn, and carrots, are sometimes used for such species as rats, voles, nutria, and jackrabbits. Fresh or canned meat and fish are used in Norway rat control. Concentrates are sold for preparing perishable-type baits.

Zinc phosphide concentrations used in baits vary greatly throughout the world, from 1 to 15% active ingredient, and this, again, demonstrates its versatility (Gratz 1973). In the U.S. it is generally used at a 1 or 2% concentration in cereal baits.

In Russia zinc phosphide has been explored as a foliar spray for microtine rodents (e.g., Microtus and related species) much the way we have used endrin and chlorophacinone as foliar sprays. The Russians have also used it as a rodent repellent for acorns destined for planting.

As a grooming toxicant, it is used as a tracking powder for house mice (Marsh 1972). It has also been evaluated in a grease base and placed at burrow entrances for rabbit control in Bangladesh (Poché et al. 1979).

WEATHERABILITY

Because zinc phosphide breaks down under wet and acid conditions, it was early thought that rapid decomposition occurred under field situations (Garlough and Spencer 1944, Doty 1945). Evidence to the contrary indicates that zinc phosphide can take a relatively long time to significantly detoxify under field conditions even when

subject to moderate rainfall (Elmore et al. 1943, Hayne 1951, Guerrant and Miles 1969). This belief that zinc phosphide breaks down rapidly when exposed to rainfall still persists and has been responsible, in part, for accidental bird losses that resulted from inadequate precautions being taken.

Physical erosion may account for most of the decrease in the toxicity of weathered baits over an extended period of time when baits are protected from rainfall.

TOXICITY TO HUMANS

Accidental poisonings of an occupational nature are rare (Haynes 1982). Stephenson (1967) reported that over a period of 48 years (1917-1965), 26 fatalities were attributed to zinc phosphide poisoning in humans; of these, 18 (70%) were suicides and 3 were murders. The fact that zinc phosphide baits are grayish-black in color and have an odor that is not particularly pleasant may contribute to few accidental ingestions. An emesis action may occur in humans from ingesting zinc phosphide, and such elimination may assist in reducing fatalities. Early characteristics of poisoning are nausea, vomiting, abdominal pain, chest tightness, excitement, and a chilly feeling. If vomiting occurs within an hour after ingestion, the chances of surviving are improved. The garlic-like smell of phosphine on the breath or vomitus of the patient is common.

POOR AND/OR INCONSISTENT EFFICACY

With species such as the California ground squirrel (Spermophilus beecheyi), the control results are often very inconsistent and erratic for reasons that seem to defy an ability to identify them, or at least all of them. It is not uncommon to have control vary from 25 to 75% for ground squirrels even on the same ranch in different years, or on adjacent ranges in the same year at the same time period. While some lack of uniform squirrel control is also experienced even with the best of acute toxicants (e.g., 1080 and strychnine), generally the reduced control can be attributed to known factors. Variabilities seen with 1080, for example, are usually very much less than with zinc phosphide.

Rarely do we achieve much better than 75 to 80% squirrel control with zinc phosphide under the best of control conditions, whereas with 1080 under similar conditions, 85 to 98% control is not uncommon.

Prebaiting, of course, can significantly improve efficacy of zinc phosphide for ground squirrels and prairie dogs just as it can with other acute toxicants. Prebaiting is often recommended, although one prebaiting may increase the cost of control by as much as 80%. In some situations, the additional cost of prebaiting may make control uneconomical.

As the same principles apply to target as well as nontarget animals, it remains unclear whether prebaiting significantly increases the hazards to certain nontarget species.

Repeated annual use over a long period of time often decreases efficacy. This has been observed in ground squirrel and vole control in California. This is due, in part, to bait shyness resulting from previous sublethal exposures. However, there seem to be other contributing factors, possibly a more discriminating population evolves. This diminished efficacy resulting from long-term use is very real, and frequently the only solution to regain reasonable control is to switch to another rodenticide.

POTENTIAL NONTARGET PRIMARY HAZARDS

Domestic mammals are rarely endangered by properly placed bait (Ingram 1945, Chitty 1954). However, fowl are highly susceptible, and there are a number of instances of chickens (Hare and Orr 1945) and domestic geese being killed where bait was accessible to unconfined, free-roaming poultry (Bubien et al. 1970).

Incidental nontarget wildlife losses are infrequent and usually involve few animals. Exceptions generally involve other seed-eating rodent species occupying the same habitat. Of the game species, geese, which are more susceptible than most target rodent species, may be the most vulnerable of all wild bird species at risk from primary poisoning (Marsh 1985). Goose mortality has occurred in the past where adequate precautions were not taken. Such past mistakes now provide a basis for specific precautionary measures. Potential hazard to ducks and pheasants (Hayne 1951, Collins 1966) has foundation, although incidental kills in the U.S. are few and relatively minor.

SECONDARY POISONING MINIMAL

Secondary poisoning of dogs and cats is not nearly as likely with zinc phosphide as with 1080 or strychnine, although the hazards of the latter two are often exaggerated. Nonetheless, on rare occasions dogs and cats have consumed poisoned rodents and died (Chitty 1954, Storer and Jameson 1965, White and Vonesch 1970, Stowe et al. 1977). Srinath (1977) mentions losses of cats and pigs in India due to secondary poisoning. Another atypical case of secondary poisoning occurred to chickens on a poultry farm in India where the birds were seen pecking at rat carcasses. About 10 chickens died as a result (Christopher et al. 1982).

Studies by a number of researchers of hazards to confined nontarget wildlife reveal minimal hazards. Siberian ferrets, a close relative of black-footed ferrets, survived the feeding of five zinc phosphide-poisoned rats, although some blood chemistries were altered (Hill and Carpenter 1982).

Zinc phosphide-poisoned prairie dogs fed to five mink for 30 days resulted in no visible symptoms of intoxication (Tietjen 1976). Coyotes receiving multiple feedings of zinc phosphide-poisoned jackrabbits showed no visible symptoms (Evans et al. 1970). Schitoskey (1975) demonstrated that kit foxes survived repeated feedings of kangaroo rats killed with massive doses of zinc phosphide. Red and gray foxes survived feedings of zinc phosphide-killed voles with no mortality (Bell and Dimmick 1975). Domestic cats and mongooses were not poisoned when fed rats poisoned with zinc phosphide (Doty 1945). Bald eagles and black vultures were not poisoned when fed zinc phosphide-killed nutria (Tietjen 1976). Those knowledgeable of rodenticides generally agree that secondary hazards to wild predators are minimal (Hegdal et al. 1980).

FUTURE PROSPECTS

There are several major shortcomings of zinc phosphide that influence its use. Relatively poor initial bait acceptance occurs in some species such as ground squirrels and prairie dogs, and serious bait and toxic shyness results from sublethal exposures in most all rodents. These contribute to the most significant shortcoming: the lack of a high degree of control effectiveness. A number of methods are thus used to overcome these shortcomings including prebaiting, microencapsulation of the active ingredient, improved bait formulations, reducing available alternate food, and better timing of application. But none of these improves efficacy to the degree that zinc phosphide could be called highly efficacious for certain field rodents. In spite of this, zinc phosphide will remain a viable rodenticide or alternate rodenticide because of its general safety.

Because of its favorable characteristics, the future of zinc phosphide will probably be good, and it will undoubtedly play about the same role in field rodent control as in the past decade. If, however, we should lose strychnine or 1080 for specific uses in controlling field rodents, then the use of zinc phosphide bait would increase substantially. Only the development of a new safer, more effective, and equally economical rodenticide would diminish the future use of zinc phosphide baits for field rodents.

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Comparative Toxicity of Strychnine to Eight Species of Ground Squirrels[1]

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Abstract.--The toxicity of 3 strychnine bait concentrations, 0.20%, 0.35%, and 0.50%, was evaluated on 8 species of ground squirrels (Spermophilus spp). Significant species-specific differences were evident in the relative toxicity of strychnine in our tests.

INTRODUCTION

The Environmental Protection Agency (EPA) completed a special review of strychnine as a rodenticide in September, 1983, and issued the PD-4 strychnine position document (EPA, 1983). The rationale for regulating strychnine-containing products was given and the studies required for the determination of the reregistration of strychnine bait formulations for ground squirrel control were listed.

The potential hazard of primary poisoning to nontarget mammals and to seed eating birds was of special concern to EPA. Thus, to reduce nontarget hazards, EPA proposed lowering strychnine concentrations from the currently registered 0.35% and 0.50% strychnine to 0.20%. Evaluation of the efficacy of the 0.20% strychnine bait through laboratory toxicity studies was essential to determine the need for testing under field conditions.

Data are presented in this report on laboratory studies on the comparative toxicity of 0.20%, 0.35%, and 0.50% strychnine on 8 species of ground squirrels (Matschke 1985a, b, c, Matschke et al. 1987d, e, f, g, h). Species tested were the Columbian ground squirrel (Spermophilus columbianus), Franklin's ground squirrel (Spermophilus franklini), golden-mantled ground squirrel (Spermophilus lateralis), Richardson's ground squirrel (Spermophilus richardsonii), rock squirrel (Spermophilus variegatus), thirteen-lined ground squirrel (Spermophilus tridecemlineatus), Townsend's ground squirrel (Spermophilus townsendii), and Uinta ground squirrel (Spermophilus armatus).

PROCEDURE

Ground squirrel procurement and care

Ground squirrels of both sexes were trapped in Montana (Columbian, golden-mantled, and Uinta), North Dakota (Franklin's), Colorado (Richardson's, rock, and thirteen-lined), Idaho (Townsend's), and South Dakota (thirteen-lined). Each ground squirrel was dusted with pyrethrum powder for flea control, and housed individually in steel cages (40.6 x 24.1 x 18.0 cm), except that rock squirrels were housed individually in stainless steel cages (61.0 x 45.5 x 23.0 cm). The animal room was maintained at about 21° C on a 12-h light-dark cycle (0600-1800 h light, 1800-0600 h dark). Squirrels were fed flaked barley, pelleted rodent laboratory chow (Ralston Purina Company[6]), and tap water (ad libitum).

Bait Formulation

Strychnine alkaloid (CAS No. 57-24-9) was purchased from Pocatello Supply Depot (PSD), Pocatello, Idaho, and assayed at 98% technical. Strychnine baits were formulated with steamed-crimped oats according to the procedures established by the (PSD) (Pocatello Supply Depot, n.d.). A sham-treated bait was formulated in the same manner with all the ingredients except strychnine. All strychnine concentrations were assayed by a procedure developed by the Denver Wildlife Research Center (unpublished) and reported as percent active ingredient. Only baits that assayed within ±10 percent of the

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[6] Reference to trade names does not imply U.S. Government endorsement.

desired concentrations, 0.20%, 0.35%, and 0.50%, were used for testing.

Testing Procedures

For each species, the number of ground squirrels tested per strychnine concentration and sex are given in Table 1.

On the day before testing, the ground squirrels were fasted beginning at 1600 h. The next morning (day 1), each ground squirrel in each strychnine treatment group received strychnine bait, and each ground squirrel in the control group received sham-treated bait. Bait was presented in aluminum dishes (8.2 cm diameter x 3.9 cm deep) fastened to the cages with metal springs. Spilled bait was caught in pans placed beneath the cages. Following presentation of test baits, the animal room was locked and entry denied until 1500 h or 1600 h the same day. Upon reentry, mortality was recorded, dishes and pans were removed from the cages of those ground squirrels that died, and remaining bait was weighed. At 0700 h the next morning (day 2), any additional mortality was recorded, dishes and pans were removed, and the remaining bait was weighed. Each survivor was given additional bait of the strychnine concentration initially received, and each control squirrel received additional sham-treated bait. Entry to the room was denied until 0700 h the next morning (day 3), when the day 2 procedure was repeated.

At 0700 h the next morning (day 4), mortality was recorded, dishes and pans were removed, and remaining bait was weighed. Survivors were given flaked barley and rodent laboratory chow, and were observed twice daily for 14 days. Records for each animal were kept on daily strychnine or control bait consumption, total bait consumption, mg of strychnine consumed per kg of body weight[7] (day 1), and mortality.

Data Analyses

For each species, differences in consumption among the 3 strychnine bait concentrations and the sham-treated bait on day 1 and between the 2 sexes were analyzed by a 2-factor analysis of variance. Comparisons of mg/kg consumption of strychnine among the 8 species for the 3 strychnine concentrations also were analyzed as a 2-factor analysis of variance. If treatment or interaction effects were significant in the ANOVA, Duncan's Multiple Range Test was used to determine which individuals means were significantly different from others.

RESULTS

Mortality

The 0.20% concentration was 100% efficacious when consumed by 3 (Franklin's, Richardson's, and thirteen-lined) of the 8 species (Table 2), and the 0.35% concentration was 100% efficacious when consumed by 6 (Columbian, Franklin's, golden-mantled, thirteen-lined, Townsend's, and Uinta) of the 8 species. The 0.50% concentration was 100% efficacious when consumed by 6 (Columbian, golden-mantled, Richardson's, rock, thirteen-lined, and Uinta) of the 8 species, and 90% or more efficacious to all 8 species. Most mortality occurred during the first 24-h feeding period for all 3 bait concentrations, with 94-97% of all squirrels dying during this period.

Bait Consumption

Consumption by ground squirrels that consumed 0.20% strychnine bait and died ranged from 0.40 to 2.18 g on day 1 (Table 3); consumption

[7] All mg/kg calculations are based on the assayed concentration of the strychnine baits.

Table 1. Sex of ground squirrels tested per species, number of ground squirrels tested per strychnine bait concentration, and total number of ground squirrels tested per species.

Species	Sex M/F	Number of squirrels per strychnine bait concentration 0.20%	0.35%	0.50%	0.0%	Total tested
Columbian	40/40	20	20	20	20	80
Thirteen-lined	40/40	20	20	20	20	80
Richardson's	40/40	20	20	20	20	80
Franklin's	40/40	20	20	20	20	80
Golden-mantled	40/40	20	20	20	20	80
Uinta	40/40	20	20	20	20	80
Townsend's	31/45	19	19	19	19	76
Rock	35/45	20	20	20	20	80

Table 2. Percent of ground squirrel mortality observed for each strychnine bait concentration.

Species	Percent strychnine bait concentration 0.20		0.35		0.50		0.0	
	N[1]	% Mortality	N	% Mortality	N	% Mortality	N	% Mortality
Columbian	13	65	20	100	20	100	0	0
Thirteen-lined	20	100	20	100	20	100	0	0
Richardson's	20	100	19	95	20	100	0	0
Franklin's	20	100	20	100	18	90	0	0
Golden-mantled	17	85	20	100	20	100	0	0
Uinta	18	90	20	100	20	100	0	0
Townsend's	18	95	19	100	18	95	2	10
Rock	16	80	18	90	20	100	0	0

[1] N = Number of ground squirrels that died.

Table 3. Mean strychnine bait consumption and mg/kg intake of strychnine for ground squirrels that died.

Species	Amount of bait given (g)	Mean strychnine bait consumed (g) - Day 1 0.20%	0.35%	0.50%	0.0%	Mean strychnine intake (mg/kg) - Day 1 0.20%	0.35%	0.50%
Columbian	5[1]	1.86±0.14[2]	1.23±0.25	1.37±0.20	-	7.82±1.62	7.82±1.62	13.46±1.74
Thirteen-lined	5[1]	0.46±0.08	0.26±0.07	0.35±0.08	-	5.48±0.85	6.35±1.54	14.30±3.35
Richardson's	10	0.44±0.09	0.35±0.07	0.19±0.06	-	3.67±0.62	3.99±0.08	3.57±1.08
Franklin's	10	0.71±0.10	0.61±0.09	0.35±0.06	-	3.18±0.39	5.47±0.77	4.92±0.80
Golden-mantled	6	0.98±0.14	0.83±0.09	0.50±0.06	-	8.58±1.24	13.67±1.52	11.66±1.40
Uinta	6	1.47±0.15	1.04±0.12	1.00±0.09	-	11.15±1.28	12.55±1.50	18.36±1.84
Townsend's	10	0.40±0.06	0.17±0.03	0.26±0.04	2.73±0.64	3.92±0.54	2.59±0.49	5.76±0.93
Rock	15	2.18±0.37	1.41±0.14	0.94±0.13	-	7.01±1.21	6.90±0.61	6.97±0.86

[1] Control given 10 g of sham-treated bait.
[2] Mean ±SE.

by survivors ranged from 0.00 to 5.58 g on day 1 (Table 4). Bait consumption by ground squirrels that consumed 0.35% strychnine bait and died ranged from 0.17 to 1.41 g on day 1 (Table 3); consumption by survivors ranged from 0.03 to 2.63 g on day 1 (Table 4). Consumption by ground squirrels that consumed the 0.50% strychnine bait and died ranged from 0.19 to 1.37 g on day 1 (Table 3); consumption by survivors was 0.0 g on day 1 (Table 4). On days 2 and 3, survivors on all 3 strychnine bait concentrations continued to consume bait Consumption by ground squirrels that consumed the 0.0% strychnine bait and survived ranged from 3.51 to 10.47 g on day 1 (Table 4).

Consumption by survivors of strychnine treated bait for the entire 3-day test averaged 10.56 g, 11.04 g, 13.34 g, and 19.56 g for the Columbian, golden-mantled, rock, and Uinta ground squirrels, respectively.

Two control animals (Townsend's) that consumed the 0.0% bait died during the 14 day posttreatment period, possibly because of environmental stress. Neither of the 2 treated Townsend's squirrels died during this time period. Sham-treated bait consumption by controls for the entire 3-day test averaged 26.48 g, 20.45 g, 11.58 g, 18.42 g, 32.28 g, 16.32 g, and 19.81 g for the Columbian, Franklin's, golden-mantled, Richardson's, rock, Townsend's, and Uinta ground squirrels, respectively. Because all 60 thirteen-lined ground squirrels on treated bait died on day 1, further testing of the 20 control animals ceased after the first 24-h feeding period.

Data Analyses

There was a significant difference among the treatment means for bait consumption (Table 5)

Table 4. Mean strychnine bait consumption and mg/kg intake of strychnine for ground squirrels that survived.

Species	Amount of bait given (g)	Mean strychnine bait consumed (g) - Day 1				Mean strychnine intake (mg/kg) - Day 1		
		0.20%	0.35%	0.50%	0.0%	0.20%	0.35%	0.50%
Columbian	5[1]	3.64±0.28	-	-	8.55±0.24	13.37±1.18	-	-
Thirteen-lined	5[1]	-	-	-	3.51±0.05	-	-	-
Richardson's	10	-	0.03±0.00	-	5.47±0.48	-	0.0±0.00	-
Franklin's	10	-	-	0.0±0.00	6.52±0.47	-	-	0.0±0.00
Golden-mantled	6	3.07±1.05	-	-	3.93±0.27	25.19±8.72	-	-
Uinta	6	5.58±0.40	-	-	6.45±0.14	30.41±0.16	-	-
Townsend's	10	0.00±0.00	-	0.0±0.00	5.98±0.43	0.00	-	0.0±0.00
Rock	10	2.96±0.77	2.63±1.77	-	10.47±0.34	8.58±2.10	10.86±6.34	-

[1] Control given 10 g of sham-treated bait.
[2] Mean ± SE.

Table 5. Treatment means for strychnine bait consumption on day 1 separated by Duncan's Multiple Range Test.

Strychnine bait concentration %	Mean grams of bait consumed[2]						
	Columbian	Thirteen-Lined	Richardson's	Franklin's	Golden-mantled	Uinta	Rock
0.00	8.55 a[1]	3.51 a	3.51 a	5.47 a	6.52 a	3.93 a	10.47 a
0.20	2.45 b	0.46 b	0.45 b	0.71 b	1.29 b	1.88 b	2.33 b
0.35	1.23 c	0.26 b	0.34 b	0.52 b	0.83 bc	1.04 c	1.54 c
0.50	1.37 c	0.35 b	0.19 b	0.27 b	0.47 c	1.00 c	0.94 c

[1] Means with no letter in common are significantly different, at an experimental-wise error rate of 0.05.
[2] ANOVA was not performed on data from the Townsend's ground squirrel due to negative consumption values.

for each species. The response was not uniform for the 8 species (excluding Townsend's[8]), except that the ground squirrels consumed significantly more of the control bait than of the strychnine-treated baits. No significant differences were found among the 3 strychnine concentrations for the Franklin's, Richardson's, and thirteen-lined. However, significant differences in bait consumption occurred among the 0.20%, 0.35%, and 0.50% concentrations for the remaining 4 species. The Columbian, rock, and Uinta consumed significantly more of the 0.20% concentration than the 0.35% and 0.50% concentrations. The golden-mantled consumed significantly more of the 0.20% concentration than the 0.50% concentration; however, no significant difference in consumption occurred between the 0.20% and 0.35% concentrations, or between the 0.35% and 0.50% concentrations for this species.

Analysis of the mg/kg of strychnine intake data among the 8 ground squirrel species that died on day 1 revealed highly significant interspecific variability ($p = 0.0005$). The results from separating the interaction means with Duncan's multiple range test are presented in Table 6. These results, plus the plot of the interaction means in Fig. 1, clearly indicate that the pattern of mg/kg strychnine consumed across concentrations is different among the 8 species. For 2 species (Richardson's and rock), mg/kg of strychnine consumed is fairly constant for all 3 concentrations. For 4 species (Columbian, thirteen-lined, Townsend's, and

[8] ANOVA was not performed on data from the Townsend's ground squirrel due to negative consumption values.

Table 6. Mean[1] intake of strychnine (mg/kg) for concentration and species of animals that died on day 1.

Concentration (%)	Species	Mortality	Mean (mg/kg)	Letter
0.2	Columbian	12	7.10	d e f g
0.35	Columbian	20	7.82	d e f
0.5	Columbian	20	13.46	b
0.2	Franklin	20	3.19	g
0.35	Franklin	18	5.78	e f g
0.5	Franklin	14	5.27	e f g
0.2	Golden-mantled	17	8.58	c d e
0.35	Golden-mantled	20	13.67	b
0.5	Golden-mantled	19	11.66	b c
0.2	Richardson's	20	3.67	f g
0.35	Richardson's	19	3.99	f g
0.5	Richardson's	20	3.57	g
0.2	Rock	16	7.01	e f g
0.35	Rock	18	6.90	e f g
0.5	Rock	20	6.92	e f g
0.2	Townsend's	18	3.92	f g
0.35	Townsend's	17	2.75	g
0.5	Townsend's	17	5.76	e f g
0.2	Thirteen-lined	20	5.48	e f g
0.35	Thirteen-lined	16	6.35	e f g
0.5	Thirteen-lined	16	14.29	b
0.2	Uinta	18	11.26	b c d
0.35	Uinta	20	12.55	b
0.5	Uinta	20	18.36	a

[1] Means with a common Letter were not significantly different at the 0.05 level of significance using Duncan's Multiple Range Test.

Uinta), mg/kg of strychnine consumed increased with increasing concentration, while for the remaining 2 species (Franklin's and golden-mantled), the mg/kg strychnine consumed was highest at the 0.35% concentration.

DISCUSSION

Our laboratory tests indicate that 3 species (Franklin's, Richardson's, and thirteen-lined) may be effectively controlled at the 0.20% or lower strychnine concentration. Four species (Columbian, golden-mantled, Townsend's, and Uinta) may be effectively controlled at strychnine concentrations between 0.20% and 0.35%. One species (rock) may be effectively controlled at strychnine concentrations between 0.35% and 0.50%. Further research will be required on all species to determine the minimum strychnine concentration that will cause 100% mortality.

Reducing the concentration of strychnine in the bait is one way to reduce the amount of toxic substance presented. Another way would be to reduce the quantity of bait applied per burrow entrance. The current directions for applying strychnine bait call for the placement of 1 tablespoon (12 g) per burrow entrance. Twelve g of bait may be excessive in view of the quantity of bait consumed by the 8 ground squirrel species. Two of the 8 species (Thirteen-lined and Townsend's) consumed no more than 1.72 g, suggesting that 2 g (1/2 teaspoon) of bait per burrow entrance may be sufficient. Four of the 8 species (Franklin's, golden-mantled, Richardson's and Uinta) consumed no more than 3.5 g, suggesting that 4 g (1 teaspoon) of bait per burrow entrance may be sufficient. For the Columbian and rock squirrel, reductions to 6 g of bait per burrow entrance may be possible, as the highest intake for a ground squirrel that died was 6.42 g.

Because survivors of 4 species (Columbian, golden-mantled, rock, and Uinta) continued to consume treated bait throughout the 3-day test period, we conclude that bait aversion did not occur under laboratory conditions. For 2 of these species (golden-mantled and Uinta), treated bait consumption by survivors equaled that of controls over the 3-day test period. While for the other 2 species (Columbian and rock), treated bait consumption by survivors was almost half the consumption by control animals.

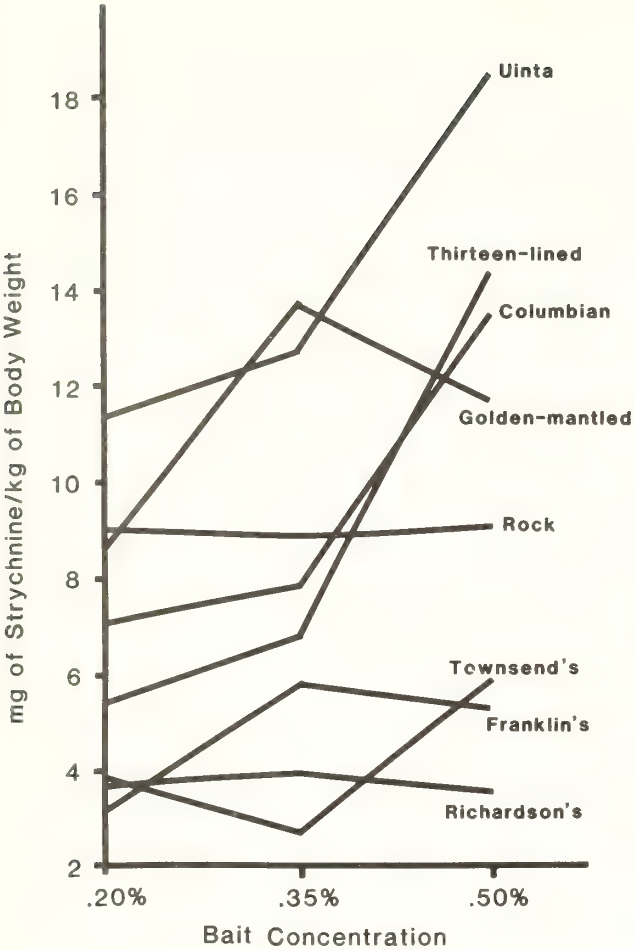

Figure 1.--Mean intake of strychnine (mg/kg) by concentration interaction for the animals that died on day 1.

The variable toxicity of strychnine to different species of ground squirrels is a function of physiological variability. The observed mg/kg of strychnine intake varied significantly among the species, and within a species, certain individuals appeared to be resistant to strychnine toxicity. Furthermore, the mg/kg intake of strychnine was constant for some species regardless of concentration, while for others, a sharp increase or decrease in mg/kg of strychnine consumed was observed at higher concentrations. Because of these differences among species, bait concentrations should be established in the laboratory before being used in the field.

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Arthropod Consumption by Small Mammals on Prairie Dog Colonies and Adjacent Ungrazed Mixed Grass Prairie in Western South Dakota[1]

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Abstract: The percentage of arthropods and plants in the diets of seven small rodents captured on prairie dog colonies and adjacent mixed grasslands were estimated by microhistological techniques. Arthropod composition over the two year study averaged 51% and 37% on prairie dog colonies and mixed grasslands, respectively. Composition of arthropods on prairie dog colonies was greater during the summer than in late spring or late summer. Conversely, arthropods made up a considerably smaller percentage of small mammal diets in the summer on mixed grasslands. Nearly twice as many small mammals, excluding prairie dogs, were trapped on prairie dog colonies than on the adjacent mixed grasslands. Prairie dog colonies favor insectivorous rodent species. Prairie dogs, in creating habitat for insectivorous small mammals, may indirectly reduce localized arthropod outbreaks.

INTRODUCTION

The black-tailed prairie dog (Cynomys ludovicianus) originally inhabited prairies from southern Canada to Mexico and from the eastern foothills of the Rocky Mountains to the tallgrass prairie (Hall 1981). Prairie dog colonies may occupy large areas of rangeland. A single prairie dog colony occupied about 64,750 square kilometers in Texas (Merriam 1902).

Because prairie dog feeding and burrowing activities conflict with the interests of livestock producers and some assume that prairie dogs influence the habitat for wildlife (Merriam 1902, Uresk et al. 1981, Hansen and Gold 1977), control of prairie dog populations has become a common practice (Merriam 1902, Uresk and Bjugstad 1983, Collins et al. 1984). However, little or no information is available on small rodents or arthropods inhabiting prairie dog colonies or the impact of prairie dog control on associated fauna. The objectives of this study were to compare small rodents, small rodent diets, vegetation, and arthropod populations on and off prairie dog colonies and provide baseline information on potential non-target impacts from prairie dog control programs.

STUDY AREA AND METHODS

The study area was located in Badlands National Park in west central South Dakota, 80 km east of Rapid City and 13 km southwest of Wall. The climate is semiarid-continental and is characterized by cold winters and hot summers. The average annual precipitation for the area is 40 cm, most of which falls as high-intensity thunderstorms during the growing season (April-September). Snowfall accumulations average 62 cm per year. Mean annual temperature is 10°C, ranging from -5°C in January to 26°C in July.

Soils are primarily sedimentary deposits of clay, silt, gravel and volcanic ash (Raymond and King 1976). The landscape includes steep gullies, sharp ridges, flat-topped buttes, spires, and pinnacles that are partly covered with vegetation and upland areas of mixed-grass prairie. Gently sloping mixed-grass sites are scattered throughout the area and are the major sites occupied by prairie dogs. The elevation of the study sites ranged from 820 m to 900 m. The study area was neither farmed nor grazed by domestic livestock but portions have been grazed and farmed in the past. Native ungulates inhabiting the area are American bison (Bison bison), pronghorn (Antilocapra americana), mule deer (Odocoileus hemionus), and white-tailed deer (O. virginianus).

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The dominant grasses of the area are western wheatgrass (Agropyron smithii), blue grama (Bouteloua gracilis), buffalograss (Buchloe dactyloides), needleleaf sedge (Carex eleocharis), needle and thread (Stipa comata), and green needlegrass (Stipa viridula). Scarlet globemallow (Sphaeralcea coccinia), American vetch (Vicia americana), lanceleaf sage (Salvia reflexa), and prairie sunflower (Helianthus petiolaris) are the most abundant forbs; fringed sage (Artemisia frigida) is the dominant shrub.

Small rodents, vegetation, and macroarthropods were sampled in 1981 and 1982. Six permanent 80- by 80-m (0.64 ha) study sites were selected for sampling small rodent and macroarthropod densities and composition and vegetation characteristics. Three sites were established on prairie dog colonies and 3 sites on mixed-grass prairie adjacent to each prairie dog colony. The mixed-grass prairie sites were 200 to 1,000 m from the prairie dog colonies. Soils were fine, montmorillonitic, mesic Aridic Argiustolls of the Norrest-Blackpipe (silty clay loam) and Nunn (loam) series. Prairie dog colonies selected had similar burrow densities.

Estimates of small rodent (not including prairie dogs) densities were evaluated on unique captures from live trapping. Sixty-four Sherman live traps, spaced at 10-m intervals, were arranged in a grid design on each site. The grids were arranged so that a 10-m border of similar habitat surrounded each trapping grid. Trapping began in May and continued at 3-week intervals through September of each year. Each sample period consisted of 1 night of prebaiting followed by 4 consecutive nights of trapping. A mixture of peanut butter and rolled oats was used both inside and outside the traps to attract small rodents. Rodents were removed from the traps, identified as to species, assigned a unique number by toe amputation, then released at the capture site.

Fecal pellets were collected from small mammals captured in Sherman live traps, placed in paper envelopes and dried. The pellets were combined for each site by species and trap session. The arthropod composition in the diets was based on 40 points and 40 fields per sample (Flake 1973). The percentage of plants in rodent feces was estimated by the microhistological technique of Sparks and Malechek (1968). Invertebrates were identified by examining composite samples by species in a petri dish at 20 power magnification and plant identification at 100 power magnification.

Ground dwelling macroarthropods were sampled by using 15 x 15-cm metal can pitfall traps (Rogers et al. 1978). Forty-nine cans were buried flush with the soil surface in a grid at 10-m spacing on each site. Pit traps were set for 4 consecutive nights at three-week intervals. Wooden lids were used to cover the traps and removed when trapping was initiated. Macroarthropods were removed, classified and counted. Actual numbers per .1 hectare as reported were based on the area pitfall traps represented on each site and converted to the hectare fraction (1/10 ha). Although this technique may underestimate less mobile arthropods and larvae (Thomas and Sleeper 1977) and flying arthropods, adequate results can be obtained for most species captured (Gist and Crossley 1973, Baars 1979).

Total plant canopy cover (2-dimensional) and annual aboveground biomass were estimated. Plant canopy cover was estimated in 150, 20 by 50-cm quadrats placed at 1-m intervals along 3, 50-m line transects at each site. Line transects were spaced 20 m apart. Canopy cover was visually estimated into 6 cover classes (Daubenmire 1959). Sampling was conducted in June (late spring), July (summer), and August (late summer) during 1981 and 1982. Aboveground biomass was calculated by harvesting 18, 1/8-m^2 circular plots each year at peak plant production on each site. In addition to sampling on grazed areas, small wire exclosures were established on prairie dog colonies and mixed grass sites in 1982 to determine the increased plant biomass with no grazing.

Factorial analyses of variance (Nie et al. 1975) were used to compare abundance of small rodents captured. One-way analyses of variance examined differences within year and treatment. Two-way analyses of variance included year by treatment. Paired T-tests were used for total percent canopy cover. Chi-square and Spearman's rank order correlation coefficient (Snedecor and Cochran 1973) were used to compare macroarthropods. Type I error level at $\alpha = 0.05$ was adapted for all tests unless stated otherwise.

RESULTS AND DISCUSSION

Small Rodents

Small rodent abundance was greater on prairie dog colonies than on mixed-grass sites (table 1). However, rodent species richness was higher ($P < 0.01$) on mixed-grass prairie sites than on the prairie dog colonies. Similar results were reported by O'Meila et al. (1982) in Oklahoma. Decreased plant canopy cover, mulch cover, biomass and vegetation height on prairie dog colonies influenced inhabitation by some small rodent species. Small rodents captured, in decreasing order of abundance, were deer mice (Peromyscus maniculatus), northern grasshopper mice (Onychomys leucogaster), prairie voles (Microtus ochrogaster), thirteen-lined ground squirrels (Spermophilus tridecemlineatus), western harvest mice (Reithrodontomys megalotis), hispid pocket mice (Perognathus hispidus), and house mice (Mus musculus). The abundance of small rodents did not vary significantly among seasons except for northern grasshopper mice.

Diet Analysis

Arthropods and plants (including seeds) were the major foods of rodents captured during the study (table 2). Arthropods represented 51% of small rodent diets on prairie dog colonies and 37% of rodent diets on mixed grass prairie sites. Arthro-

Table 1.--Mean[1] abundance (numbers/1000 trap nights) by years of small mammals on prairie dog colonies and on adjacent mixed grass prairie sites without prairie dogs in western South Dakota during 1981 and 1982.

Species	1981		1982	
	Prairie Dog Colonies	Mixed Grass Prairie	Prairie Dog Colonies	Mixed Grass Prairie
deer mouse	17 ± 2^{a}	8 ± 3^{b}	41 ± 6^{c}	10 ± 3^{b}
northern grasshopper mouse	11 ± 2^{a}	4 ± 9^{b}	13 ± 3^{a}	$2 \pm .6^{b}$
prairie vole	0 ± 0^{a}	$<1 \pm .1^{a}$	0 ± 0^{a}	15 ± 2^{b}
thirteen lined ground squirrel	$<1 \pm .1^{a}$	6 ± 2^{b}	$<1 \pm .07^{a}$	$5 \pm .9^{b}$
western harvest mouse	0 ± 0^{a}	$1 \pm .4^{b}$	0 ± 0^{a}	$3 \pm .9^{b}$
hispid pocket mouse	0 ± 0^{a}	$1 \pm .5^{b}$	0 ± 0^{a}	$2 \pm .7^{b}$
house mouse	$<1 \pm .07^{a}$	$<1 \pm .07^{a}$	$<1 \pm .07^{a}$	0 ± 0^{a}
Total	28^{a}	20^{b}	54^{c}	37^{d}

[1]Means within a row with the same superscript are not significantly different at ($P < 0.01$).

Table 2. Mean percentage of arthropods and vegetation in the diets of seven small rodents by season on prairie dog colonies and adjacent mixed-grass prairie sites in western South Dakota during 1981 and 1982.

Year	Late Spring				Summer				Late Summer			
	Prairie Dog Colonies		Mixed Grass		Prairie Dog Colonies		Mixed Grass		Prairie Dog Colonies		Mixed Grass	
	Arthropod	Vegetation	Arthropod	Vegetation	Arthropod	Vegetation	Arthropod	Vegetation	Arthropod	Vegetation	Arthropod	Vegetation
deer mouse												
1981	36.5	63.5	52.2	47.8	66.3	33.7	31.8	68.2	61.3	38.7	32.0	68.0
1982	15.3	84.7	53.3	46.7	51.8	48.2	13.0	87.0	55.4	44.6	78.9	21.1
Average	25.9	74.1(1)	52.8	47.2(2)	59.1	40.9(3)	22.4	77.6(4)	58.4	41.6(5)	55.5	44.5(6)
northern grasshopper mouse												
1981	48.8	51.2	56.0	44.0	82.5	17.5	42.2	57.8	45.8	54.2	58.2	41.8
1982	34.0	66.0	81.1	18.9	79.5	20.5	71.2	28.8	—	—	63.4	36.6
Average	41.4	58.6(7)	68.6	31.4(8)	81.0	19.0(9)	56.7	43.3(10)			60.8	39.2(11)
prairie vole												
1981			0.0	100.0			1.6	98.4			—	—
1982			17.0	83.0			19.8	80.2			44.3	55.7
Average			8.5	91.5(12)			10.7	89.3(13)				
thirteen lined ground squirrel												
1981	29.7	70.3	33.4	66.6			51.8	48.2			32.0	68.0
1982	—	—	.8	99.2			65.8	34.2			49.5	50.5
Average			17.1	82.9(14)			58.8	41.2(15)			40.8	59.2(16)
western harvest mouse												
1981			79.0	21.0			15.0	85.0			77.8	22.2
1982			6.5	93.5			16.5	83.5			20.1	79.9
Average			42.8	57.2(17)			15.8	84.2(18)			49.0	51.0(19)
hispid pocket mouse												
1981			26.5	73.5			3.3	96.7			45.9	54.1
1982			—	—			1.0	99.0			2.4	97.6
Average							2.2	97.8(20)			24.2	75.8(21)
house mouse												
1981	0.0	100.0					9.5	90.5				
1982	—	—					—	—				
Average												

(1) % seeds is 42.4 (2) % seeds is 22.6 (3) % seeds is 34.0 (4) % seeds is 56.0 (5) % seeds is 30.2 (6) % seeds is 34.0 (7) % seeds is 35.0
(8) % seeds is 25.0 (9) % seeds is 15.2 (10) % seeds is 25.6 (11) % seeds is 29.2 (12) % seeds is 15.0 (13) % seeds is 19.8 (14) % seeds is 48.8
(15) % seeds is 16.6 (16) % seeds is 43.2 (17) % seeds is 51.6 (18) % seeds is 59.6 (19) % seeds is 32.8 (20) % seeds is 87.8 (21) % seeds is 68.3

pods were consumed in the greatest quantity during the summer of 1981 on prairie dog colonies (fig. 1). During the same sample period, arthropod composition was at a low on adjacent mixed grasslands. Arthropod composition on mixed grasslands was highest in the late summer of 1982 while arthropod composition on prairie dog colonies was lowest during the late spring of 1982. Generally, composition of arthropods during the late spring and late summer sampling periods were similar between prairie dog colonies and mixed grasslands, however arthropod composition on prairie dog colonies increased significantly during the summer sampling period and decreased on mixed grasslands. Sieg et al. (1986) reported peak consumption of arthropods by deer mice occurring in the summer and the lowest consumption in the spring on bentonite mine spoils in Montana.

The most common arthropods in the diets of small rodents were of the orders Coleoptera, Hymenoptera, and Orthoptera (table 3). Johnson (1961) and Flake (1973) also reported the importance of these arthropods in small rodent diets in Idaho and Colorado, respectively.

The high proportion of arthropods consumed in this study (particularly prairie dog colonies) is related to the high density of carnivorous and omnivorous rodents occupying the area and is consistent with several studies (Johnson 1961, Whitaker 1966, Flake 1973, Hansen 1975, Hingtgen and Clark 1984, Sieg et al. 1986).

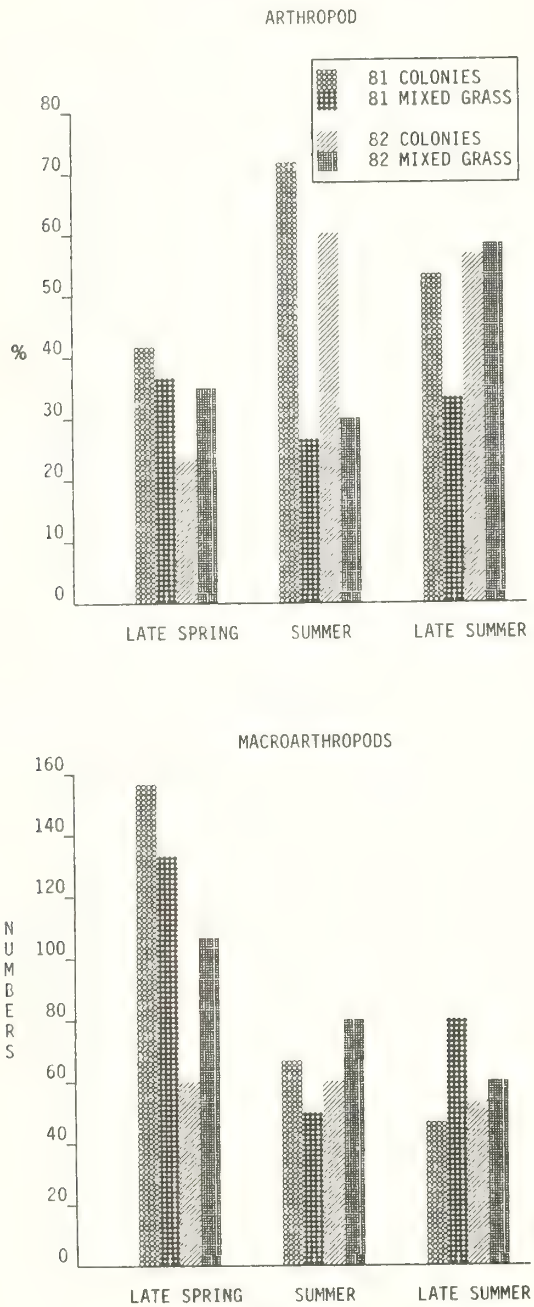

Figure 1.--Percent arthropod composition found in small mammal feces and mean abundance (numbers/.1 ha) of macroarthropods by season on prairie dog colonies and on adjacent mixed grass prairie without prairie dogs in western South Dakota during 1981 and 1982.

Table 3.--Composition of major arthropods found (%) in small rodent feces on prairie dog colonies and mixed grass prairie sites in western South Dakota during 1981 and 1982.

Arthropod Taxa	Prairie Dog Colonies	Mixed-Grass Prairie
Acari	0.6	0.0
Araneida	3.2	3.3
Coleoptera	61.2	37.9
Coleoptera larvae	0.0	0.3
Diptera	0.2	0.0
Hemiptera	0.0	0.3
Hymenoptera	16.1	25.4
Lepidoptera larvae	8.2	7.5
Orthoptera	9.5	20.9
Unknown	1.0	4.4
	100.0	100.0

Plants were consumed in greater quantity on mixed grass prairie sites having greater numbers of herbivorous small rodents. Composition of plant matter increased on prairie dog colonies from 1981 to 1982 while arthropod composition increased on mixed grasslands during the same period.

In 1981, vegetation standing crop averaged 1,024 kg/ha and 1,644 kg/ha on prairie dog colonies and mixed grasslands, respectively without cages. In 1982, the average production increased to 1,235 kg/ha and 3,177 kg/ha on prairie dog colonies and mixed grass sites. The increase in production was attributed to an increase in the amount of precipitation in 1982 (69%) over the same period in 1981. Precipitation in 1981 was 96% of normal. The average aboveground biomass in 1982 under wire exclosures was 1822 kg/ha (48% increase compared to outside exclosures) and 3111 kg/ha (2% decrease) on prairie dog colonies and mixed grass sites, respectively.

The increased plant biomass in exclosures on prairie dog colonies is not surprising as many studies have documented that prairie dogs clip vegetation in order to maintain an unimpeded watch for predators (Hall 1955, Koford 1958, Tileston 1961, Agnew 1983, Agnew et al. 1986). Plant canopy cover on mixed-grass prairie sites was significantly greater in late spring and late summer of 1982 compared to that on prairie dog colonies (fig. 2). Cover values were similar during 1981 and in summer 1982.

Macroarthropods

Macroarthropods are a dynamic but poorly understood component of the rangeland ecosystem (Hewitt et al. 1974). Macroarthropod captures on prairie dog colonies and mixed grasslands were highly variable throughout 1981 and 1982.

Borror and DeLong (1971) reported macroarthropod distribution as species specific and highly variable between localities. O'Meilia et al. (1982) reported macroarthropod biomass was three times greater on areas without prairie dogs than on adjacent prairie dog colonies. Total macroarthropod densities in this study slightly favored mixed grasslands.

Macroarthropod numbers/.1 ha ranged from 156 in the late spring to 45 in the late summer in 1981 on prairie dog colonies (fig. 1). In 1982, the densities remained relatively constant at 61 in the late spring and summer, then declined to 52 in the late summer. Macroarthropods on mixed grass prairie sites ranged from 132 in the late spring trapping period to 50 in the summer and 79 in the late spring of 1981. This was the only instance where macroarthropod densities were **greater** ($P < .05$) in the late summer than the late spring or summer periods. In 1982, the abundance of macroarthropods ranged from a high of 107 in late spring to a low of 60 in the late summer. Total macroarthropod numbers for summer and late summer sample periods during both years were similar, however, overall macroarthropod taxa composition and abundance was quite different between sites (table 4).

A significant decrease in the number of macroarthropods captured in late spring 1982 may be related to above normal winter and spring moisture. Mills (1952) and Atkins (1978) reported that precipitation can act as a direct cause of insect mortality. Insect eggs and small larvae can be permanently washed from their host plants by heavy rain or may drown in saturated soils. Many other authors (Huddleston et al. 1975, Lavigne and Campion 1978, Thomas 1979) stressed the importance of reliable precipitation in the reproductive success of insects and for herbage production and subsequent food availability.

Sieg et al. (1986) reported an increase in arthropod consumption by deer mice during periods

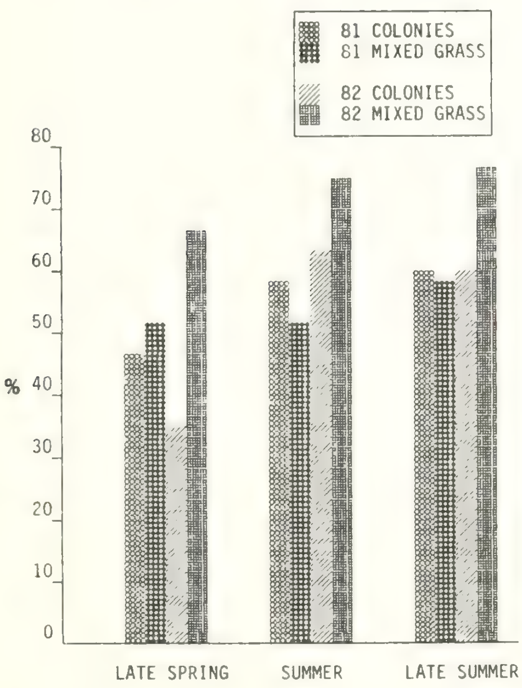

Figure 2.--Seasonal canopy cover of plants on prairie dog colonies and on adjacent mixed grass prairie without prairie dogs during 1981 and 1982.

Table 4.--Mean (±SE) abundance (numbers/.1 ha) of macroarthropods on prairie dog colonies and on adjacent mixed grass prairie sites without prairie dogs in western South Dakota during 1981 and 1982.

Macroarthropod taxa[1]	Prairie dog colony	Mixed grass prairie
Class Insecta		
Hymenoptera Formicidae	112 ± 28	137 ± 27
Coleoptera Histeridae	48 ± 10	14 ± 5
Coleoptera Carabidae	39 ± 8	14 ± 3
Coleoptera Tenebrionidae	18 ± 4	21 ± 5
Orthoptera Gryllidae	8 ± 2	19 ± 5
Diptera	5 ± 1	12 ± 6
Coleoptera Chrysomelidae	3 ± 2	<1 ± <1
Orthoptera Acrididae	2 ± <1	16 ± 6
Coleoptera Meloidae	1 ± <1	<1 ± <1
Lepidoptera	1 ± <1	7 ± 2
Coleoptera Silphidae	<1 ± <1	5 ± 2
Hemiptera Reduviidae	<1 ± <1	2 ± 2
Class Arachnida		
Aranedia Lycosidae	19 ± 6	36 ± 7
Aranedia Thomisidae	5 ± 5	<1 ± <1
Aranedia Clubionidae	2 ± <1	2 ± <1
Acarina	2 ± 1	14 ± 8
Araneida Theridiidae	2 ± 2	1 ± <1
Araneida Loxoscelidae	1 ± 1	<1 ± <1
Class Crustacea		
Isopoda	<1 ± <1	2 ± 1
Class Chilopoda	<1 ± <1	<1 ± <1
Class Diplopoda	<1 ± <1	0
Total	267 (Σ=33)	295 (Σ=36)

[1]Macroarthropods representing <1 per .1 ha include: Coleoptera Cocciellidae, Coleoptera Scarabaeidae, Hemiptera Lygaeidae, Coleoptera Curculionidae, Hymenoptera, Araneida Gnaphosidae, Hymenoptera Mutillidae, Hemiptera Anthocoridae, Hymenoptera Sphecidae, Coleoptera, Coleoptera Cerambycidae, Coleoptera Elateridae, Coleoptera Cinindelidae, Coleoptera Melyridae, Odonata, Phalangida.

of decreased moisture and plant production. Similarly, in this study, small rodents on prairie dog colonies increased arthropod consumption during periods of below normal precipitation, however, arthropod consumption decreased during periods of below normal precipitation on mixed grass prairie sites.

Higher than normal precipitation may have negatively impacted macroarthropod densities in 1982, however, the lower number of macroarthropods reported is also related to the near two fold increase in small rodents on prairie dog colonies and mixed-grass prairie sites.

Ants were the most commonly trapped macroarthropod on both treatments (table 4). Ant densities varied greatly between years and throughout the growing season, on and off of prairie dog colonies.

Ant abundance in late spring was higher ($P < .01$) on both prairie dog colonies and mixed grass sites in 1981 when compared to 1982. Other commonly trapped macroarthropods were beetles (Coleoptera), crickets and grasshoppers (Orthoptera), spiders (Araneida), flies (Diptera), butterflies and moths (Lepidoptera) and mites (Acarina). Macroarthropods trapped less frequently include true bugs (Hemiptera), daddy-long-legs (Phalangida), millipedes (Diplopoda), dragonflies (Odonata), saw bugs (Isopoda), and centipedes (Chilapoda).

The rank order of macroarthropod taxa on the two treatments was positively ($P < 0.1$) correlated ($r = .68$) for the two years. This indicates that composition (ranking) based on numbers of captures was somewhat correlated between the two treatments.

CONCLUSION

Prairie dogs act as ecosystem regulators by maintaining short-grass plant associations with less cover, lower vegetation height and production. These vegetative features, combined with high burrow densities, provide quality habitat for some species of small rodents, such as deer mice and grasshopper mice. However, vegetative manipulation by prairie dogs negatively impacts rodent species associated with dense vegetation of mixed-grass sites. The influence prairie dog activity has on the diets of small rodents inhabiting prairie dog colonies is evident in the greater percentage of arthropod fecal composition and the higher densities of insectivorous and omnivorous small rodents on prairie dog colonies. Yearly and seasonal differences in macroarthropod densities can be attributed to precipitation variations and associated vegetation changes and to increased small rodent densities.

Although the role of prairie dogs as ecosystem regulators is not fully accessed, these results indicate that prairie dogs influence small mammals, arthropods, and vegetation. Prairie dog control programs can influence the vegetation successional patterns on prairie dog colonies and create mixed grass plant associations. Associated prairie dog control impacts will also influence small rodents and arthropods common on prairie dog colonies.

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Small Mammals: Pests or Vital Components of the Ecosystem[1]

Carolyn Hull Sieg[2]

ABSTRACT.--Small mammals regarded as "pests" should not be viewed separately from other components in the ecosystem. Small mammals have significant influences on vegetation and soils, exert predatory pressure on other animals, and provide food for predators. Future management efforts should include consideration of these diverse influences.

Careful evaluation of the role of small mammals and their relationships with their environment is necessary to fully appreciate the impact of control programs on the ecosystem. Small mammals regarded as "pests" should not be viewed separately from other components in the ecosystem. Rather, small mammals must be viewed in terms of their interrelationships with other components. Alteration of small mammal communities through control programs influence other components and ultimately the whole system.

Small mammal influences may be grouped as those effects on (1) vegetation, (2) soils, and (3) other animals. Vegetative influences may include effects on primary productivity, plant species composition, and decomposition rates of plant materials. Small mammals influence both physical and chemical properties of soils. Small mammals prey on insects and occasionally other small mammals, provide a prey base for carnivores, and modify their environments in such a way as to provide habitat for other animals.

INFLUENCES ON VEGETATION

Researchers have proposed various ways in which small mammals interact with plant communities. The main interactions can be categorized as those relating to primary productivity, plant species composition, plant stature and reproduction, and decomposition rates of plant materials.

Primary Production

Small mammal herbivores may consume as much as 60% (Migula et al. 1970) to 80% (Taylor and Loftfield 1942) of the total annual primary plant production. They may have localized, large-scale impacts on primary productivity during population explosions. However, the effect of direct consumption of plants by herbivores must be evaluated in terms of what portion of the primary production is actually available to the animal. Estimates of herbage consumption by small mammals ranged from <1% in northern shortgrass and midgrass sites to as much as 20% in desert grasslands (French et al. 1976). Harris (1971) estimated that 0.17-5.01% of the net primary production was transferred to the rodent trophic level. Hayward and Phillipson (1979) concluded that the impact of small mammal consumption on net or available primary production is negligible in most systems.

Light grazing by small mammals may stimulate plant production. For example, moderate grazing by voles (Microtus oeconumus and M. middendorffit) increased production of two plant species by stimulating new shoot growth (Smirnov and Tokmakova 1971, 1972). Regrowth of rye grass (Lolium perenne) that had been grazed by hispid cotton rats (Sigmodon hispidus) was faster than regrowth of grass that had been mechanically clipped (Howe et al. 1982). The authors speculated that either a biochemical agent in saliva or the specific manner of tissue removal by the cotton rats stimulated regrowth of the rye grass.

Plant Species Composition

Small mammals have been credited with changing plant community composition and species distribution. Rodents and rabbits have been cited as major agents responsible for range destruction (Taylor 1936). Other authors (e.g., Smith 1940) viewed the presence of these small mammals as a symptom of poor range condition, rather than a cause. Small mammals have been credited with assisting in the control of undesirable plants. Plant communities in Montana, Utah, and Nevada were altered by extensive damage to

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big sagebrush (Artemisia tridentata) during cyclic population peaks of voles (Microtus spp.) (Mueggler 1967, Frischknecht and Baker 1972). Control of pocket gophers (Thomomys talpoides) in western Colorado resulted in an increase of perennial forbs (Turner 1969); grass and sedge densities were higher in areas where gophers were present in Utah (Ellison and Aldous 1952). However, small mammal herbivory may also reduce densities of plants viewed as "beneficial" by land managers. Selective grazing by meadow mice (Microtus californicus) kept the habitat open and increased plant species diversity; when mice were excluded grasses increased and became dominant (Batzli and Pitelka 1970).

Small mammals can also alter plant community composition and species distribution by consuming and caching seeds. Rodents have been blamed for poor establishment of seeded plants and large scale failures of tree crops (Smith and Aldous 1947, Gashweiler 1970). Small mammals can further influence plant community composition by heavily grazing or damaging plants, and thus reducing their ability to produce seeds (Batzli and Pitelka 1970). Severe grazing by montane meadow mice (Microtus montanus) and deer mice (Peromyscus maniculatus) decreased biomass and seed production of cheatgrass (Bromus tectorum) in eastern Washington (Pyke 1986).

Seed caching activities can alter plant distribution by either increasing or decreasing survival of plants. The harvest and storage of grass seeds by meadow mice was estimated to reduce seed fall of preferred food plants by 70% in some areas in California (Batzli and Pitelka 1970). Yet, dispersal of seeds by small mammals can result in increased germination and survival. Seeds are often moved to better germination sites and seeds that normally have a "clumped" distribution pattern (as below the parent plant) are often scattered, or consumed, resulting in less dense stands (Reichman 1979). West (1968) estimated that 50% of the bitterbrush (Purshia tridentata) and 15% of the ponderosa pine (Pinus ponderosa) plants in central Oregon resulted from rodent seed caches. Consumption of wild oats (Avena fatua) and wild barley (Hordeum leporinum) seeds by meadow mice and house mice (Mus musculus) reduced densities of these two plants by 62% and 30%, respectively, allowing for increases in plant size and seed production of wild barley, Italian ryegrass (Lolium multiflorum), and bromegrasses (Bromus mollis and B. diandrus) (Bochert and Jain 1978).

Some organisms may be dependent on small mammals for seed or spore dispersal. Truffles and other hypogeous fungi depend on mammal and invertebrate mycophagy for spore dispersal (Fogel and Trappe 1978). Small mammals may serve as effective agents in the dispersal of mycorrhizal fungi and nitrogen-fixing bacteria. Viable nitrogen-fixing bacteria, yeast, and spores of mycorrihizal fungi all survived passage through the digestive tracts of forest rodents captured in western Oregon (Li et al. 1986). These results suggest that small mammals can innoculate recently disturbed soils, as after fires (Li et al. 1986) and in mined areas (Sieg et al. 1986). In this manner, pioneering small mammals may help initiate plant succession and increase survival of new plants.

The rate of plant succession may be affected by small mammal burrowing and feeding activities. Prairie dog mounds disrupt grass associations and provide bare soil for the invasion of lower successional plants. Pocket gopher mounds provide bare soil on which secondary plant succession may begin (Larrison 1942), thereby increasing the diversity of plants (Laycock 1958). Investigations following the Mount St. Helens eruption suggest that northern pocket gophers (Thomomys talpoides) may be an important agent in determining succession in volcanically disturbed areas. Pocket gophers bring pre-eruption soils to the tephra surface; plant survival on the pocket gopher mounds has exceeded survival on adjacent areas (Anderson and MacMahon 1985). Selective herbivory by small mammals can also alter plant successional rates. Rodents may aid in the recovery of overgrazed grasslands by selectively grazing on "weedy" plant species (Gross 1969). Grazing by California ground squirrels (Spermophilus becheyi) decreased the abundance of filaree (Eroduim botrys) and lupine (Lupinus bicolor) on Californian grasslands, while smooth bromegrass, a grass of higher successional stage than the forbs, increased (Horn and Fitch 1942).

Decomposition of Plant Materials

Small mammals can influence the rate of decomposition of organic materials by adding green herbage and excrements to the litter layer and by reducing the particle size of vegetative material. They are more efficient in effecting the mineralization of organic matter than either insects or ungulates (Golley et al. 1975). As much as 58% of the total herbage harvested by small mammmals on a shortgrass prairie was not consumed (Scott et al. 1979). These "wastage" activities may be important in accelerating decomposition rates of plant materials. Green plant material that becomes litter decomposes more rapidly that brown plant material (Grant and French 1980). Voles affect decomposition rates by altering microclimatic conditions in the litter layer and by deposition of excrements and vegetative cuttings into litter layers, which increases microorganism growth (Zlotin and Kodashova 1974). Reduction of particle size of living and dead vegetative material by small mammals also increases decomposition rates.

INFLUENCES ON SOILS

Soil structure and chemical composition are affected by the activities of small mammals. Soil structure is largely influenced by burrowing activities. Burrowing and the addition of feces and urine to the soil influence soil chemical composition through changes in nutrient and mineral cycling rates and pathways.

Soil Structure

Soil structure may be altered as small mammals burrow, bringing large quantities of mineral soil

to the surface. Pocket gophers are reported to excavate 18 metric tons of soil material per hectar per year (Hole 1981). Abaturov (1968) estimated that mole burrows covered 36% of woodland ground surface, which resulted in increased soil porosity and drainage, and altered soil water holding capacities. Pocket gophers tended to increase porosity and lower bulk density of soils in a subalpine grassland in Utah (Laycock and Richardson 1975). However, in seeded mountain ranges in Utah (Julander et al. 1959), pocket gopher activity packed the soil surface, lowered infiltration rates, and decreased available soil moisture.

Mima mound microrelief is another modification of the physical structure of the environment that has been attributed to small mammals. These mounds are characterized by a lower bulk density, less soil structure, and increased water permeability compared with neighboring undisturbed soil (Ross et al.1968). Soil mounds resulting from small mammal burrowing are strongly heated, and the surface crust that rapidly forms prevents evaporation. As a result, at depths of 5-20 cm the water content of the soil under mounds is 7-8% higher than that at corresponding depths in virgin soil (Zlotin and Kodashova 1974).

Chemical Composition

The most significant role of small mammals may be their effect on the chemical composition of soils, particularly the addition and incorporation of nitrogen (Taylor 1935). Soil chemical composition can be altered by the addition of small mammal excreta and by the upward displacement of nutrients through the soil profile. Feces and urine add to the organic matter content in soils, increase available nitrogen levels, and possibly influence the growth of Azotobacter (Kucheruk 1963 [cited in Hayward and Phillipson 1979]). Greene and Reynard (1932) estimated that the average kangaroo rat (Dipodomys spectabilis) burrow contained 2 kg of nitrate. Small mammals influenced the nitrogen flux on shortgrass prairies more than any other vertebrate, but less than either belowground or aboveground invertebrates (Woodmansee et al. 1978).

The concentration of other minerals may also be influenced by small mammal activities. High concentrations of soluble calcium, magnesium, and bicarbonate were reported in kangaroo rat burrows by Greene and Reynard (1932). Mole (Talpa europea) burrowing returned large quantities of leached calcium and magnesium to the zone of intense plant root activity (Dinesman 1967). Older prairie dog mound soils had higher pH values, and phosophorous values equal or greater than adjacent nonmound soils (Carlson and White 1987).

INFLUENCES ON OTHER ANIMALS

Small Mammals as Predators

Small mammals function as secondary consumers in the ecosystem by preying on invertebrates and on other mammals, which may have direct impacts on prey populations and indirect influences on primary production. Insectivorous species may exert a regulatory effect on invertebrate populations; small mammals consumed a high percentage of invertebrate populations in nearly all grassland sites studied by French et al. (1976). Carnivory has been shown to influence prey species densities. Hayward and Phillipson (1979) estimated that weasels (Mustela nivalis) consumed as much as 14% of the small mammal production, resulting in a reduction in the impact of small mammals on the rest of the ecosystem.

Secondary consumption may indirectly influence primary production. Plant consumption by invertebrate herbivores may be reduced by the insectivorous feeding habits of small mammals. Destruction of large numbers of larch sawfly larva by shrews was reported by Buckner (1964). Small mammal predation may serve to reduce invertebrate species that are themselves predators of phytophagous insects. Field mice (Apodemus sylvaticus) were responsible for a 50% reduction in an overwintering population of Hymenopteran cocoons (Obtrel et al. 1978). Interactions between insectivorous mammals and their food sources have received less attention than the interactions of small animals with primary production food sources, and therefore the extent to which invertebrate populations are regulated by insectivory is largely speculative.

Small Mammals as Prey

Small mammals serve as a food supply for a large number of predators and can exert significant influence on predator population cycles. Small mammals, especially rodents, are characterized by high productivity rates, and thus, even at relatively low densities, are an important source of food for predators. Densities of small mammals can have profound impacts on the reproductive potential of some predators. For example, the proportion of tawny owls (Strix aluco) that bred each year in England varied from 0 to 80%, according to the number of mice and voles present (Southern 1970). Several authors have documented cases where population levels of predators can be traced to small mammal densities. For example, population declines in black-tailed jackrabbits (Lepus californicus) induced significant decreases in numbers of coyotes (Canis latrans) in northwestern Idaho and southern Idaho (Clark 1972) and kit foxes (Vulpes macrotis) in western Utah (Egoscue 1975). Raptors, such as the great-horned owl (Bubo virginianus), may increase as much as five-fold during years of high densities of snowshoe hares in Alberta (McInvaille and Keith 1974). Further, population outbreaks of small mammals can induce predators to switch from preferred prey, thus reducing predation on some game species (Leopold 1933).

Small Mammals as Home Builders

Small mammals also influence other animals and arthropods by altering the environment in ways that provide habitat for other species. For example, bird densities and species richness were higher on prairie dog towns than on adjacent mixed-grass communities in South Dakota (Agnew et al. 1986).

Prairie dog burrows provide nest sites and escape cover for burrowing owls (Athene cunicularis), prairie rattlesnakes (Crotalus viridis viridis), and a variety of small mammals and arthropods (Costello 1969). Mounds made by moles (Scalopus spp.) become habitats of such animals as arthopods, amphibians, and reptiles (Hole 1981).

SUMMARY

Management decisions to control small mammals usually stem from perceived negative values associated with the offending species. However, as managers increasingly focus on ecosystem management, the positive role of small mammals on vegetation, soils, and other animals may be of interest. Further, public interest in a diversity of habitats and animals should induce managers to balance animal control efforts with efforts to maintain diversity in ecosystems. Small mammals can have significant influences on vegetation and soils, exert predatory pressure on insects and other mammals, and also provide food for other predators. It appears that small mammals fill important and perhaps indispensible roles in ecosystem function. They are interconnected in complex ways with other biotic and abiotic components of the ecosystem, and future management efforts should focus on these relationships to a greater extent than in the past.

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Historical and Present Status of the Black-Footed Ferret[1]

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Abstract.--The black-footed ferret (Mustela nigripes) was once widely distributed in the Great Plains and intermountain valleys of North America, its range overlapping the combined ranges of several species of prairie dogs (Cynomys spp.). Most life history information has been obtained from studies of ferrets in southwestern South Dakota (1964-1974) and studies near Meeteetse, Wyoming (1981-present). The ferret's nearly complete dependence on prairie dogs was documented in both study areas. The recent collapse of the Meeteetse population of ferrets due to an outbreak of canine distemper underscores the threat posed by this disease, but reductions of prairie dogs by man and other diseases are also potentially harmful. Eighteen animals are being held for captive breeding, no free-ranging ferrets have been located, and species recovery seems dependent on captive propagation and releases.

INTRODUCTION

The black-footed ferret (Mustela nigripes) is a member of the family Mustelidae. The long, slender animals weigh 650 to 1400 grams; adult males are about 47% heavier than adult females (Anderson et al. 1986). The historic range of the black-footed ferret was coextensive with the combined ranges of the black-tailed prairie dog (Cynomys ludovicianus), the white-tailed prairie dog (C. leucurus), and Gunnison's prairie dog (C. gunnisoni). The black-footed ferret is nearly totally dependent on the prairie dog ecosystem, and any prairie dog management program potentially affects the ferret's welfare. The black-footed ferret is now perhaps North America's rarest mammal. We review the ferret's historic distribution and abundance, summarize more recent developments, and present perspectives on the animal's future.

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HISTORIC DISTRIBUTION AND ABUNDANCE

Audubon and Bachman introduced the black-footed ferret to the scientific world in 1851, although Indians of several Great Plains tribes were already familiar with the animal (Clark 1976). Some authors have implied or categorically stated that the ferret was always uncommon, although others (e.g., Henderson et al. 1969, Hillman and Carpenter 1980) have qualified their remarks by pointing out the difficulties of finding ferrets even when they are known to be present. Evidence suggesting historical rarity includes use of ferret parts in Indian ceremonies (Fortenberry 1972), the relatively late discovery of the ferret, and the paucity of reports and specimens. However, our experiences with ferrets near Meeteetse, Park County, Wyoming, support the implication by Linder et al. (1972) that ferrets were seldom reported simply because they are fossorial, nocturnally active, and thus difficult to observe. The ferret population in Park County was the largest known for the species, yet few residents had ever seen one and they were not "discovered" until 1981. Researchers usually had to locate ferrets using high-intensity spotlights, equipment unavailable to the natives and early settlers of the Great Plains.

Some early records of the black-footed ferret came from trappers. Such records are sparse, but the American Fur Company received

86 ferret skins from Pratt, Chouteau, and Company of St. Louis in the late 1830's (Johnson 1969). Fur traders of that era must have recognized the North American ferret by its similarity to its Eurasian relatives. In the early 1900's, trappers involved in animal control operations undoubtedly took many ferrets; 25% of the specimens reported by Anderson et al. (1986) were taken in this manner. The proportion of ferret specimens saved relative to total number trapped is unknown. During the early years of predator control, ferrets may have been discarded as having no particular value; in later years, recognition of the animal's rarity may have caused the same response--this time out of fear of reprisal or even legal action (after passage of the Endangered Species Act of 1973).

Anderson et al. (1986) recorded the status of 412 black-footed ferret specimens from 12 states and 2 Canadian provinces. Sight reports were not considered because of difficulty in assessing their authenticity; nevertheless, their list supports an original widespread occurrence of the ferret, and suggests that it was a common animal in at least portions of its range. We join others (Linder et al. 1972, Hubbard and Schmitt 1984, Anderson et al. 1986) in questioning the commonly accepted axiom that the black-footed ferret was "always rare." The data of Anderson et al. (1986) indicate an increase in specimens collected through the 1920-1939 period (fig. 1). This increase probably reflects increased attention given the species rather than change in the ferret population. Efforts to find ferrets continued to increase in later years, underscoring the precipitous decline in specimens obtained.

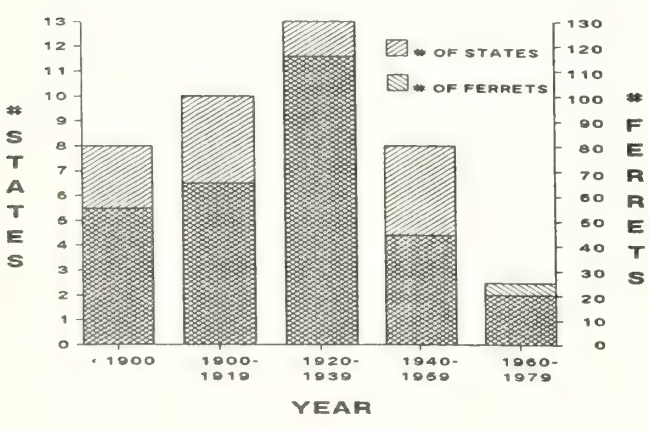

Figure 1. Numbers of black-footed ferret specimens collected and number of states (U.S.) and provinces (Canada) represented (data from Anderson et al. 1986).

RECENT HISTORY--1960 TO PRESENT

During the 1960's and 1970's, ferret specimens for which approximate date of death could be established originated only from South Dakota, Montana, and Wyoming (fig. 1). In the 1970's, all such specimens came from Mellette County (South Dakota), Park County (Wyoming), and Carter County (Montana), although unverified sightings were reported from other areas and states.

Most knowledge of black-footed ferret life history was obtained from studies conducted in Mellette and adjacent counties, South Dakota, during 1964-1974, and in Park County, Wyoming, during 1981-1986. In South Dakota, 11 ferret litters were observed by biologists from 1964-1972 (Linder et al. 1972), but searches failed to reveal ferrets on the Mellette County study areas after 1974. In Wyoming, 70 ferret litters were observed by researchers from 1982-1986; the highest minimum count of ferrets for a single year was 129. An outbreak of canine distemper decimated the Meeteetse population in 1985 (Forrest et al., in press); the last known animal was removed in 1987 for captive breeding.

An attempt at captive propagation of South Dakota ferrets began in 1971, with the capture of six animals; another individual was added to the founder stock in 1972, and two more in 1973 (Carpenter and Hillman 1978). Four of the original six animals died of vaccine-induced canine distemper shortly after capture (Carpenter et al. 1976). Litters of young were produced during two consecutive years by one female, but none survived more than two days. The last of these captives died in 1978 (Carpenter et al. 1980).

A second attempt to captive breed began in 1985, with the capture of six ferrets from Meeteetse. Two of the animals developed symptoms of canine distemper soon after capture, indicating that they had been exposed to the virus before capture (Williams et al., in manuscript). All six ferrets died of the disease; the last four animals apparently contracted it from the first two. Six more ferrets were captured late in 1985, eleven in 1986, and one in 1987; these 11 females and 7 males form the current captive breeding program in Wyoming.

THE FERRET DECLINE--MORE QUESTIONS THAN ANSWERS

Life history studies in South Dakota and Wyoming underscored the nearly complete dependence of black-footed ferrets on prairie dogs. Prairie dogs (particularly the black-tailed species) may have increased in the late 1800's and early 1900's due to heavy overgrazing (Clark 1973); their numbers were then greatly reduced by control programs and

conversion of prairies to croplands. Sylvatic plague, a disease that may have been introduced into North America (Eskey and Haas 1940) also can cause massive prairie dog dieoffs (Barnes 1982). The ferret decline may be related to an overall decline in prairie dogs, but ferrets have decreased proportionately more than their prey, suggesting involvement of other factors.

Disease and genetic problems could have been influential in the ferret decline. Studies of black-footed ferrets from Meeteetse revealed the population has low levels of genetic variation (O'Brien et al., in press), indicating a possible genetic bottleneck at some time in the past. The combination of maladies suffered by captive ferrets from the Mellette County, South Dakota population also was suggestive of inbreeding (Carpenter et al. 1981). The extreme susceptibility of the black-footed ferret to canine distemper became evident during the first experiences with captive ferrets from South Dakota. A modified live virus vaccine that was sufficiently attenuated for use on European ferrets (Mustela putorius) produced fatalities in black-footed ferrets (Carpenter et al. 1976). Erickson's (1973:159) suggestion that "the hazards of exposure of the highly sensitive black-footed ferret to canine distemper virus may be substantial" proved prophetic when the Meeteetse population was devastated by the disease in 1985. Blood tests conducted on other carnivores present in the study area showed that some coyotes (Canis latrans) and badgers (Taxidea taxus) had been exposed to canine distemper virus, which suggests a broader scale epizootic with many potential routes for interspecific transmission.

An incomplete understanding of disease, genetics, small population biology, and habitat loss allows synthesis of a wide variety of scenarios to explain how black-footed ferret numbers were reduced to their present level. In the process of considering possibilities, questions such as the following seem relevant:

1. Did prairie dog reductions fragment ferret habitat (i.e., prairie dog towns) sufficiently to create small, insular subpopulations of ferrets, each with greatly increased risk of "chance extinction" (Harris et al., in press) resulting mostly from the ferret's characteristically large seasonal fluctuation in numbers?

2. Did prairie dog reductions result in sufficient fragmentation of ferret habitat to isolate remaining black-footed ferrets, leaving subpopulations that would become inbred?

3. Is hypersensitivity of black-footed ferrets to canine distemper a result of inbreeding?

4. Did the black-footed ferret historically have to cope with canine distemper epizootics?

5. Does a discontinuous distribution of black-footed ferret populations offer protection from extincton due to a canine distemper epizootic by providing barriers against intraspecific transmission of the disease?

6. Would a large, geographically continuous population of ferrets be better able to survive a distemper epizootic through reinvasion by survivors?

7. What role does interspecific transmission of canine distemper play in the dynamics of the disease?

On the other hand, the explanation for the decline of ferrets is not necessarily as complex as implied above. If settlement of the Great Plains exposed the ferret to a new disease with which it had not evolved, then the ferret might have been taken to the verge of extinction regardless of prairie dog reductions, population isolation, or genetic problems. Canine distemper has become increasingly suspect in the ferret decline, but the Meeteetse case history is the only documentation of the disease in free-ranging black-footed ferrets; its impact on other ferret populations is unknown.

THE FUTURE

The black-footed ferret has little chance for recovery without an agressive program of captive propagation. The immediate goal must be preservation of the gene pool; without that, there are no future options. If all future populations of black-footed ferrets are produced from the present captive animals, genetics will be a major concern (Ballou, in press). A comprehensive effort to locate more ferrets is imperative, with the primary objective of increasing genetic variation in the captive population. A prerequisite for reintroduction of ferrets is maintenance of complexes of prairie dog colonies as ferret habitat. The prospect for successful reintroduction of ferrets would be enhanced by (perhaps depends on) a better understanding of factors that placed the ferret in its current status.

Potential problems with genetics, disease, and available habitat imply that some level of perpetual management action will be needed to ensure persistence of reintroduced populations. A possible management strategy

could include maintenance of several captive populations in addition to the reestablished wild populations, exchange of animals between populations (Brussard, in press), a program for monitoring wild populations, and use of releases and transplants to rapidly rebuild any population reduced by diseases or other catastrophes.

After the ill-fated experience with South Dakota ferrets, Carpenter et al. (1981:746) suggested that ferret recovery faced "more formidable obstacles than previously envisioned." That statement clearly remains appropriate after the Meeteetse case history. Nevertheless, an impressive array of resources and expertise has been assembled to address problems of ferret recovery, and, with good fortune, the black-footed ferret may yet be returned from the brink of extinction.

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A Field Habitat Model for Black-Footed Ferrets[1]

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Abstract.--We present a model to compare prairie dog complexes with known black-footed ferret habitat. The model assumes: 1) black-footed ferret populations require prairie dog colonies for survival, 2) prairie dog colonies can accommodate an additional black-footed ferret for each approximate 50 hectare increase in size, 3) a higher percentage of overall area covered by prairie dogs can accommodate more black-footed ferrets. We list four biological variables. They are: 1) total hectares in prairie dog colonies, 2) percent of total complex inhabited by prairie dogs, 3) intercolony distance, 4) an estimate of burrow density per hectare. In addition, two non-biological parameters are included. They are development potential and land ownership patterns. The model can provide an initial critique of a prairie dog complex for a black-footed ferret search or as a reintroduction site.

INTRODUCTION

Black-footed ferrets (*Mustela nigripes*) appear to depend on prairie dogs (*Cynomys* spp.) for food and shelter. Of 310 museum specimens listed by Anderson et al. (1986), only six were collected outside prairie dog range. Biggens et al. (1985) reported telemetered ferret location highly correlated with prairie dog towns.

In South Dakota, 91% of black-footed ferret diet was prairie dog (Sheets et al., 1969). In Meeteetse, a food habit study showed 87% of black-footed ferret scats contained prairie dog remains (Campbell et al., 1987). Powell et al. (1985) estimated a caloric intake of 110-130 Kcal per day, and speculated a ferret would kill one prairie dog a week during winter. A female raising a litter would have to increase her rate of predation. Observations by Paunovich and Forrest (pers. comm.) indicated a female with a litter of five may have been killing .6 prairie dogs per day. Therefore, any area containing prairie dogs can be considered black-footed ferret habitat.

In this paper we present a model which evaluates prairie dog complexes where black-footed ferrets were known to occur in Wyoming. A prairie dog complex is defined as a group of individual prairie dog colonies. The biological parameters follow the outline of the habitat suitability index (Houston et al., 1986). It differs from that model in four ways. Our model uses four biological variables instead of five, we use simple linear relationships, we have added two non-biological parameters, and our model can be calculated rapidly without the use of a pocket computer.

The model can serve two functions. First it is a relatively inexpensive method to search for undiscovered populations of black-footed ferrets. Second, our model provides a rapid method for initial identification of prairie dog complexes to be considered for more extensive study as reintroduction sites. A model that could then be applied to these screened sites is the black-footed ferret habitat suitability index of Houston et al. (1986).

The data upon which our model is based comes from two black-footed ferret populations, one in South Dakota on a black-tailed prairie dog (*Cynomys ludovicianus*) complex, and the

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other from the Meeteetse population located on a white-tailed prairie dog (Cynomys leucurus) complex. Because our model is based on data from both ferret populations, we believe that it can be useful throughout the original black-footed ferret range.

MODEL BACKGROUND

Ferrets are solitary. Females display smaller home ranges than males (Biggins et al., 1985; Richardson et al. in press) with one male home range typically overlapping the ranges of several females. Within a sex, however, there is little spatial or temporal overlap (D. Biggins, pers. comm.), a pattern typical of mustelids (Powell, 1979).

The Meeteetse prairie dog complex has prairie dog densities varying from 2 to 20 per hectare (Menkens unpubl. data). At maximum Black-footed ferret densities in Meeteetse, Forrest et al. (1985) estimated an adult ferret occupied about 50 hectares of prairie dog habitat. This relationship was constant whether calculated over individual colonies or over the entire complex. The 50 hectares of habitat per ferret therefore appears to be a linear relationship. The black-footed ferrets at the Meeteetse site existed on a complex of 18 colonies ranging from 12.5 hectares to 1302 hectares in size (Forrest et al., 1985). The total prairie dog acreage was 2790 with a mean intercolony distance of 0.9 km. (Forrest et al., 1985).

The black-footed ferret model therefore makes the following assumptions:

1) black-footed ferret populations require prairie dog colonies for survival
2) prairie dog colonies can accommodate an additional black-footed ferret for each approximate 50 hectare increase in size
3) a higher percentage of overall area covered by prairie dogs can accommodate more black-footed ferrets

MODEL DEVELOPMENT

We used four biological parameters for evaluation of prairie dog complexes. They are: 1) total hectares prairie dog colonies, 2) percent of complex area inhabited by prairie dogs, 3) intercolony distance within the complex, and 4) burrow density. These variables are sufficient to evaluate a prairie dog colony or complex for a black-footed ferret search effort. If the purpose of the evaluation is to investigate potential reintroduction sites, two non-biological variables are added: 1) development potential, and 2) land ownership patterns.

Total hectares occupied by prairie dog colonies can be calculated from accurate mapping of the prairie dog complex. This variable assumes the larger the prairie dog colonies in the complex, the greater the potential for a viable black-footed ferret population. On black-tailed prairie dog colonies in South Dakota, Hillman et al. (1979) recommended a 12 hectare minimum colony size for individual black-footed ferrets, and a 40 hectare minimum for females with a litter. In Meeteetse, the maximum black-footed ferret density was one black-footed ferret for every 50 hectares over 2800 hectare area (Forrest et al., 1985). The smallest prairie dog colony supporting an individual black-footed ferret was 12 hectares, and the smallest colony supporting a litter was 50 hectares (Forrest et al., 1985).

Percentage of the total complex area in prairie dog colonies assumes the greater the percent area occupied by prairie dogs, the better the black-footed ferret habitat. Percent area occupied by prairie dog colonies can be calculated by drawing a polygon around the colonies comprising the complex, and calculating the area inside the polygon. Total area of prairie dog colonies (variable 1) is divided by the area of the polygon to calculate this variable. The Meeteetse prairie dog complex has about 22% of the total area occupied by prairie dogs (Houston et al., 1986), and the South Dakota site has about 1.7% of its area inhabited by prairie dogs (Hillman et al., 1979).

The third variable is average intercolony distance. We assume that smaller intercolony distances lead to higher quality black-footed ferret habitat. Large intercolony distances may make intercolony travel and dispersal more difficult (MacArthur and Wilson, 1967). Intercolony distance is about .9 km. at the Meeteetse site (Forest et al., 1985), and about 2.4 km. at the Mettetse County site in South Dakota (Hillman et al., 1979). Intercolony distance can be calculated by measuring the shortest boundary distance between colonies on a map.

The fourth variable is burrows per hectare. Black-footed ferret habitat quality is affected by the density of both prairie dogs and their burrows. There is no rapid technique to estimate prairie dog density since populations fluctuate (Menkens, 1987). Our model therefore accepts the presence of prairie dogs as sufficient. We can, however, count the prairie dog holes. Burrow densities are not a reliable indicator of prairie dog density (Menkens et al. in press; King, 1955), but burrow density is an important part of the prairie dog ecosystem for the black-footed ferret. They provide the ferret with shelter, and allow escape from predators. Selected plots can be sampled, and the burrow numbers averaged. The prairie dog complex can be classed into one of six categories of burrow density per hectare.

If a site is being evaluated for a search effort, these four biological variables are sufficient. If it is being considered for reintroduction of captive raised black-footed

ferrets, two subjective non-biological variables are added.

The first is development potential. The sequence from worse to best case includes: 1) heavy development (such as a strip mine) that will obliterate most of the habitat; 2) moderate development with the potential to expand to heavy development; 3) moderate development, but well planned to mitigate effects to wildlife; 4) light development, but with potential expansion; 5) light development that is well planned; and 6) no development pending.

The second variable is land ownership patterns. The sequence from worst to best case is: 1) hostile or uncooperative; 2) a complex situation with multiple owners that presents potential cooperation problems; 3) private ownership which is cooperative, but unstable economically; 4) private ownership which is stable, but owners have mixed feelings about ferrets and the activities associated with reintroduction; 5) an even mix of stable private ownership, and federal land; and, 6) all or most of the land in federal ownership with the remainder friendly and stable. It is important to recognize that development potential and land ownership patterns can sometimes change.

MODEL USE

Each variable in the model has 6 categories. We have assigned a value to each of these categories. If the purpose of the evaluation is to prioritize prairie dog complexes for a black-footed ferret search effort, only the first 4 variables are used. To produce a total, add the appropriate value for each variable and divide by four. There will then be a comparative score representing the particular prairie dog complex. If the purpose of the evaluation is to choose potential black-footed ferret reintroduction sites that are worthy of further analysis, use all 6 variables. Again, add the appropriate value for each variable. Then, divide this total by 6 to assign the prairie dog complex a comparative score. In table 1 and 2 we present the variables in the model with the relative value assigned to each of their categories. In table 3 , we offer a comparative score of the Meeteetse site and another complex.

Table 1. Biological variables of the habitat model

Variable 1. Total hectares in prairie dog colonies.

Value	Hectares
1	0000-1500
2	1500-3000
3	3000-4500
4	4500-6000
5	6000-7500
6	7500

Variable 2. % hectares of the prairie dog complex in prairie dog colonies.

Value	%
1	0-10%
2	10-15%
3	15-20%
4	20-25%
5	25-30%
6	30%

Variable 3. intercolony distance

Value	Distance
1	1.5
2	1.5-1.2
3	1.2-0.9
4	0.9-0.6
5	0.6-0.3
6	0.3-0.0

Variable 4. burrows per hectare

Value	Burrows
1	0-15
2	15-30
3	30-45
4	45-60
5	60-75
6	75

Table 2. Non-biological variables of the habitat model

Variable 5. development potential

Value	
1	heavy development
2	moderate development with potential expansion
3	moderate development well planned for wildlife
4	light development with potential expansion
5	light development well planned for wildlife
6	no development pending

Variable 6. land ownership patterns

Value	
1	hostile
2	complex ownership situation with potential problems
3	private ownership is cooperative, but unstable economically
4	stable private ownership, but owners reluctant or unsure
5	mix of stable private ownership and federal land
6	most or all federally owned

Table 3. Application of the model to the Meeteetse site, and a prairie dog complex in southwestern Wyoming on which a black-footed ferret skull was located.

Meeteetse would score:

Variable	Value
1	2
2	4
3	4
4	4
5	5
6	5

The score for the first 4 variables would be 3.5. The score for all 6 variables would be 4.0.

The complex in southwestern Wyoming would score as follows:

Variable	Value
1	1
2	5
3	4
4	2
5	2
6	2

The comparative score for the first 4 variable would be 3. The comparative score using all 6 variables would be 2.7.

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A Novel Strategy for Pocket Gopher Control[1]

Michael E. R. Godfrey[2]

Abstract. Current techniques for the control of pocket gophers use traps, fumigants or toxic baits. Trapping and fumigation are labor intensive and seldom effective in giving more than short-term relief. Toxic baiting usually uses baits that are rapidly degraded and although the resident gopher may be killed the burrow system is frequently reoccupied very rapidly and little long-term control is achieved. The use of persistent baits that remain toxic and acceptable to the gophers for an extended period may result in more effective long-term control.

INTRODUCTION

Pocket gophers are major pests of agriculture and forests throughout extensive areas of the United States of America. Three species dominate, the Northern Pocket Gopher (*Thomomys talpoides*) in the Pacific Northwest, the Valley Pocket Gopher (*Thomomys bottae*) in the Southwest and the Plains Pocket Gopher (*Geomys bursarius*) east of the Rocky Mountains.

The damage attributed to gophers is as diverse as the range of habitats they occupy. They destroy the root systems of fruit trees in orchards throughout the Northwest, they are a major cause of reforestation failures in the western states (Barnes 1973, Tunberg et al 1984), and are serious pests of agriculture, particularly sprinkler-irrigated alfalfa, where more than 440 gophers per ha have been recorded (Tickes 1983).

Significant reductions in yield of fruit and alfalfa occur and harvest machinery may suffer extensive damage from hitting gopher mounds. Irrigation systems, underground power and telephone cables and home gardens may also be destroyed by gophers (Stewart and Baumgartner 1978).

Barnes (1973) reported that up to 67% of planted ponderosa pine seedlings may be destroyed while Ronco (1970) found 4 - 54% annual mortality in spruce seedlings and 3 - 30% mortality on contorta pine. Gophers may cause the complete failure of plantations (Barnes 1973, 1974, Canutt 1970, Capp 1976, Crouch 1971).

The burrow system created by a single gopher may cover half a hectare with burrows ranging from just below the surface to over 60 cm deep. Gophers are normally solitary except during the breeding season but will rapidly invade an unoccupied system (Stewart and Baumgartner 1978, Tunberg et al 1984). One other characteristic of note is that gophers store food in nests or other enlarged chambers (Stewart and Baumgartner 1978) and these food caches may be eaten by other gophers that invade the burrow system following the death or disappearance of the original occupant (Tunberg et al 1984).

CONTROL STRATEGIES

Many different strategies have been used in attempts to control the various species of pocket gophers. However, many of the methods are only effective in specific locations or conditions and no method gives consistent long term control (Tunberg et al 1984). Mortality of at least 75% is necessary to give any degree of long term relief (Barnes 1973) and 90% mortality has been suggested as necessary before a significant long-term reduction in damage is obtained (Capp 1976).

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Cultural Practices and Exclusion

In limited areas where intensive maintenance is possible exclusion may be feasible to protect a valuable crop. A barrier at least 60 cm into the ground is necessary. Alternatively, crop rotation may be of some benefit by creating periodic unfavorable conditions but this too is a method of very limited applicability (Case 1983, Tickes 1983,). A band of cereal grain grown as a perimeter to an alfalfa field may be effective as a barrier if the enclosed field is cleared of all resident gophers. Flood irrigation may also be effective in some areas but has very limited applicability (Case 1983).

Trapping

Trapping is only effective with very low population densities due to the number of traps needed to catch all the gophers present and the return visits inherently necessary in a trapping program. It is extremely slow and time consuming although it is a widely used technique in forest operations (Barnes 1973), due largely to a lack of more efficient methods able to be used in cut-over areas. It is often not cost effective either (Tickes 1983).

Fumigation

Several fumigants are registered for use in gopher control. However, they are not effective in sandy or dry soils where the gas may rapidly dissipate (Case 1983, Stewart and Baumgartner 1978,) and, again, in all but low density populations the time and cost of using this control method is prohibitive. Smoke cartridges may be useful in indicating the extent of a particular burrow system however.

Toxic Baiting

The use of toxic baits for the control of pocket gophers has been practiced for many years but often with only inconsistent or limited success. Various formulations of baits containing strychnine have been the most widely used with zinc phosphide and first generation anticoagulants used to a more limited extent, either on loose grain or in pellets (Case 1983, Canutt 1970, Handley 1978, Marsh 1987, Tickes 1983,). Wheat, milo and oats are the major ingredients in most baits although just about every type of grain has been used either alone or in various mixtures. Some products are not registered for use in all states and others have various restrictions on their use such as a limit to hand application only. (Case 1983, Marsh 1987, Tickes 1983,).

With the use of acute toxicants the rapid onset of symptoms may cause poison shyness or tolerance may develop reducing the level of control achieved (Anthony et al 1984, Case 1983, Tickes 1983, Tickes et al 1982,). Further, not all gophers potentially exposed to the poison may be able to find sufficient bait to kill them (Tickes 1983). The bait may be mixed or covered with soil and go unnoticed as the runway is extended or filled during foraging (Tickes 1983). In areas of high humidity and excessive moisture treated grain baits often become damp, caked or mouldy which reduces their palatability (Barnes et al 1985, Marsh and Pleese 1960, Ray 1978). Conversely, bait spilled on the ground during application can create a hazard to ground feeding birds (Case 1983).

Baits are usually applied by hand, using probes or other means of getting the bait into the burrow, or through the use of mechanical burrow builders. Hand baiting is much faster than trapping but is still too slow to allow adequate treatment of extensive areas (Barnes 1973), particularly if several return visits are necessary to maintain an acceptable level of control. The burrow builder is substantially faster allowing large areas to be treated but its use may be restricted by soil conditions, topography and obstructions (Barnes 1973) and some skill is required to operate the equipment well (Tickes 1983). Dry soil will crumble preventing the formation of a satisfactory burrow and obstructions such as rocks and stumps may limit the accessible area, a common situation in reforestation programs. Further, the artificial burrows may expedite reinvasion by gophers or other rodents and may even expand the infested area so that the end result may be worse than the original situation.

The selection of the toxicant to use with a burrow builder is also limited. The first generation anticoagulants are not considered to be suitable for use in small pellets or as loose grain at the current toxin loadings as the gopher must eat too much over too great a distance to receive a lethal dose (Marsh 1987). This may be overcome, however, by formulating the baits at a higher strength thereby reducing the amount of bait necessary to be lethal. There has been interest in using anticoagulants for some time, however, due to the numerous desirable characteristics inherent with their use. The availability of the second generation materials was thought to overcome some of the problems found with earlier materials, especially the relatively large quantity of bait that had to be consumed over several days. Unfortunately, these compounds have not been markedly more successful when used experimentally in field trials than many of the older products (Kaukeinen and Rampaud 1986, Poche' 1986).

These various shortcomings in the techniques available to control pocket gophers have been recognized for a long time and numerous studies have been made to overcome them. The use of larger, more durable baits is an approach that has received a lot of attention. Cardboard or plastic tubes filled with various grain and paraffin mixtures and several different toxicants have been evaluated in numerous studies as a way to get a larger amount of toxicant to a gopher at a single site. These studies gave some indication of the

potential of this strategy of concentrating a large amount of toxicant in one bait (Tunberg et al 1984). Solid paraffin and grain blocks of various sizes have also been evaluated on numerous occasions, particularly by Howard and Marsh (Lee 1986, Marsh 1987, Tunberg et al 1984). These paraffined baits are more moisture resistant than conventional baits and so remain acceptable for some time. Consequently, they contain ample bait for multiple feedings and they remain fresh so that invading animals may also find and eat enough bait to receive a lethal dose (Lee 1986). Tunberg et al (1984) had up to 4 gophers killed by a single bait over a 40 day period. Thus, not only may the initial level of control be improved but the use of persistent baits may also help control gophers in systems missed when the bait was applied, or new invaders from untreated areas (Lee 1986), a problem frequently identified (Capp 1976, Couch and Frank 1979, Tunberg et al 1984). Marsh (1987) found that because of the delayed death when anticoagulants were used in durable baits the gopher often ate all the bait and so none was left for others. Attempts to slow down the feeding so that some bait remained were largely unsuccessful. Wood chips, sand, pea gravel, hard plastic or salt were used in the baits but were discontinued as some animals would refuse the baits. Placing baits in plastic bags was not successful either as some gophers ejected the bags from their burrows although they were well accepted in laboratory trials (Lee 1986). Lee (1986) found that pocket gophers readily accepted the paraffin baits and mortalities up to 100% were achieved in her trials. Almost invariably the gophers died underground too thus reducing the risk of secondary poisoning.

If acute toxicants are used the blocks can be small as little bait is needed to be lethal to any gopher eating the bait. However, if anticoagulants are used the baits need to be large as the gopher will eat a substantial amount of the bait before dying. Baits of about 100 g are large enough to kill the resident gopher and still have some bait left for later invaders. It is also apparent that gophers are able to move baits of this size to their food caches (Tunberg et al 1984) which may increase the probability of them being found and fed upon subsequently.

Following on from this extensive background of research J. T. EATON & COMPANY. INC. have formulated a bait containing the anticoagulant diphacinone and shaped it for ease of placement in gopher burrows. It weighs about 110 g and therefore is large enough to kill the resident gopher and still remain in sufficient quantity to be lethal to a subsequent invader.

In our own studies an initial pen trial with four juvenile northern pocket gophers indicated that they would readily accept the paraffin blocks. All four died within seven days. Although alternative food was continuously available the gophers ate over 90% of the bait offered indicating that the baits were well accepted.

In a field study in early June, a time not usually suitable for treatment as there is often little apparent sign of gopher activity, substantial population reductions occurred. Two orchard blocks totalling about 6 ha were treated. These areas would have been trapped otherwise as the soil was unsuitable for the use of burrow builders. As the orchard was regularly irrigated, only mounds 2 or 3 days old were apparent and many other gophers may have been active but not recorded as their burrow systems were not located. At each identified active system only one half of a 100 g paraffin bait block was placed in each end of the main burrow after it was opened with a shovel. The burrow was then closed. Two weeks later each plot was reassessed by recording the number of active mounds. Every burrow system identified as active at the reassessment was then rebaited and assessed again a further two weeks later.

Gross reductions of 50% and 69% in the number of obviously active mounds were recorded following the first bait application and overall reductions of 77% and 88% were recorded after the second application.

Due to the effects of regular irrigation it is most likely that numerous complete systems were not detected and therefore not baited but could have been recorded in the post poisoning assessments. Thus the assessed mortality is likely to be substantially less than occurred in the gophers which were actually exposed to the baits. Further, the treated areas were relatively small with large perimeters and migration of gophers from untreated adjacent areas probably occurred. In normal control operations these areas would also have been treated.

The bait applications were done by totally inexperienced orchard workers who readily accepted the technique but who could have missed some systems. Thus, it is reasonable to assume that applications during the more preferred poisoning seasons of spring and fall with experienced applicators would yield significantly better results. Further, results from comparable adjacent areas which were heavily trapped yielded population reductions of only about 20%.

In retrospect, substantially more bait should have been placed in each opened burrow. Whereas only a total of 100 g was placed in each identified system the use of a whole block placed in each exposed end of the burrow may have resulted in even better control by ensuring that more bait was available for gophers occupying the burrow following the death of the original occupant.

Later trials have indicated that these baits withstand weathering for over two months while remaining acceptable and toxic.

The use of a new product,"EATON'S ANSWER for the Control of Pocket Gophers", was effective in controlling gophers in a situation where other techniques were ineffective. The product has been improved from the baits used in the initial trials

and now provides a persistent bait which will be acceptable and effective against gophers that invade the system sometime after the original occupant has died.

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Rodent Damage to Various Annual and Perennial Crops of India and Its Management[1]

Ranjan Advani [2]

Abstract.--The results of about 12 years' study deals with rodent damage to several annual and perennial crops of India including cereal, vegetable, fruit, plantation and other cash crops. The rodent species composition in order of predominance infesting different crops and cropping patterns percent damages and cost effectiveness of rodent control operations in each crop and status of rodent management by predators are analysed.

INTRODUCTION

Rodents, as one of the major important vertebrate pests (Advani, 1982a) are directly related to the production, storage and processing of the agricultural crops and their eventual utilisation by man and its livestock for food, fibre and protection. In India, where malnutrition and starvation are best known to exist due to disparity between human population and available food, the rodents eat about 10 percent of agricultural production. Moreover, as India is situated in tropical and subtropical regions of the world with green vegetation available throughout the year, the turn over rate of rodents is much faster than other biomes of the world. In the world, rodents are responsible for the annual loss of about 33 million tones of stored cereals and rice alone (WHO, 1974).

In some of the crop fields with important crops in North India, reduction in rodent populations through integrated pest management techniques yielded cost return ratios to the extent of 1:900 (vegetables, Advani and Mathur, 1982), 1:247 (wheat, Advani, et al 1982) 1:220 (stored grains, Prakash et al 1981). To bring down the rodent populations at low level, control operations for six continuous crop seasons (two/year) are necessary (Advani, et al 1987) in cereal and vegetable crops. However, hitherto no authentic and quantified information exists for other crops like maize, rice, barley, sugarcane, all tuberous and fruit crops, arecanut, oil palm, etc. Whereas, some attempts and preliminary investigations in cocoa and coconut crops yielded information that pods and nuts worth of rupees 500 and 650 respectively can be saved when one rupee is spent on trapping of rodents in the plantations (Advani, 1982b).

The damage magnitude and association of various rodent species with their respective crops studied so far, are presented.

METHODS

The results presented in this communication mostly pertain to the studies conducted in twelve villages near Jodhpur (Rajasthan, North India) and eight villages in Kasaragod (Kerala) and Mangalore (Karnataka, South India). The population ecology and dynamics of rodents were studied after Prakash (1975), whereas, the assessment of damages by rodents to different annual crops were evaluated after Greaves et al (1977). For damage assessment in the coconut and cocoa crops (perennial), methodology of Williams (1971, 1974) was followed. Control operations were carried out after Prakash (1977).

RESULTS AND DISCUSSION

Vegetable crops

In Rajasthan, studies in twelve vegetable crops in twelve villages, showed predominance of Indian desert gerbil, Meriones hurrianae; Indian gerbil, Tatera indica and Soft-furred field rat, Rattus meltada in the infested crop fields. The small field mouse, Mus booduga and a gerbil, Gerbillus gleadowi were also damaging the vegetables mainly tomato and brinjal. The rodent damage to various crops ranged from 4.1 to 19.9 percent, the average being 8.7 percent (Advani and Mathur, 1982). As a result of trapping, control and other management practices, rodent populations reduced by 92.5%. The rodent damage also declined by 91.9 percent and the production of crops increased (on an average) by 7 percent per hectare. The cost benefit ratio of rodent control work was 1:900 (in rupees).

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Chilly

Chilly is a main crop of the farmers of Rajasthan and is exported to neighbouring states in India and to middle-east Arab countries. The average rodent damage to this crop was 18.8, 11.48, 27.85 and 25.74 percent at sowing vegetative growth, maturity and threshing stages respectively (manuscript). As a result of continuous management practices, the relative rodent damage reduced by 89.89, 77.60, 85.79 and 83.5 percent respectively to these four stages of growth. This increased the production by about 16.1 quintals/ha, the cost benefit ratio being 1:571 (in rupees). Along with three predominant rodents, M. hurrianae, T. indica and R. meltada; the Bust rat, Golunda ellioti gujerati, and Indian palm squirrel, Funambulus pennanti were also captured in higher numbers from the crop fields. In several cases, the M. hurrianae were found to thrive upon chilly in storage as exhibited by their stomach contents.

Wheat

In three varieties of wheat, Desi (local), Kharchia (salt tolerant) and Kalyansona (hybrid) the average rodent damage was quantified to be 18.66, 21.28 and 16.29 percent respectively (Advani et al 1982). The cost benefit ratio obtained after two years' work on rodent pest management practices was, 1:247. T. indica predominated the Kalyansona and Kharchia varieties of crops, whereas, M. hurrianae infested the Desi variety, in more relative abundance. Third species, R. meltada which has shown its preference for wheat crop in field as well as storage (Rana and Advani 1981) also occurred in moderate densities. Along with rodents shrew, Suncus murinus sindensis, hitherto known as insectivorous, was also found to feed upon wheat (Advani and Rana, 1981).

Millet

About 90 percent farmers of the Rajasthan state depend upon millet (summer-rainfed crop) for their family needs. Out of seven species infesting millet, M. hurrianae, T. indica, R. meltada and G. ellioti were four major rodents infesting this crop (Advani 1982b). The damage inflicted was about 15.0, 7.6 and 20.1 at sowing, vegetative, growth and harvesting stage. Management of about 90 percent of rodent populations resulted into cost: return ratio of 1:267 (Advani et at 1981).

Oil seeds

About 8 percent of rodent fauna captured during five years' studies (1977 to 1981) in twelve villages in Rajasthan, was found to infest oil seed crops, mainly Sarson (Advani, 1982a). R. meltada, F. pennanti, G. ellioti were three main pests besides two predominant gerbils, infesting this crop. The percent damage was 5.5, 6.09, 10.8 at sowing, growth and harvesting stages respectivesly. In Gujarat, about 50 percent of ground nut was being damaged by the field rodents (B.D. Rana personal communication).

Coconut

Rodent damage at a level of 28.5 percent was evaluated in West coast variety of the coconut (Advani, 1982b) in Western Ghat biome of South India. IN the hybrids DxT, TxD) and Laccadive variety it was ranging from 10.2 to 20.5 percent. The House rat, Rattus rattus was the predominant rodent species occurring in about 70 percent of relative abundance. This species is a major pest of stored grains in houses and godowns in Rajasthan (Prakash et at, 1981), with the highest average litter size (6.60±0.10) among all rodents and the 27.03/young ones/female annual productivity rate (Rana et al 1982). Among other species, the Field mouse, Mus booduga and the Bandicoot rats, Bandicota bengalensis, Bandicota indica and Indian gerbil, Tatera indica cuvieri were also captured from nurseries of coconut. To the inflorescence of coconut, the Western ghat squirrels, Funambulus tristriatus also damages in higher magnitudes. In a single instance about 250 male flowers and capsules were plucked by a single animal in one hour. Regular trapping of rodents with local traps for four months reduced the damage by over 76 percent, resulting into return of Rs. 650 when only one rupee was spent on labor and cost of trap. In Lakshadweep, as much as 6 million coconuts worth of 35 lakhs rupees are damaged per year (Whitaker and Bhasker, 1978 Shah & Subiah 1978). The estimated loss to coconut crop is about 55 percent in Minicoy island (Advani, 1984b) and 35 percent in Car Nicobar groups of islands in Bay of Bengal (Advani, Unpublished data).

Cocoa

A heavy damage (75 percent) can be seen by rodents in any of the farmers' fields having cocoa plantations (Advani, 1982b). With predominance of Rattus rattus and Western ghat squirrel, Funambulus tristriatus, three mammalian species, like Long-tailed tree mouse Vandeleuria oleracea; a fruit bat, Cynopterus sphinx and House shrew, Suncus murinus were also collected in rodent traps. The Indian flying fox, Pteropus giganteus also damages cocoa pods besides coconut, banana guava, grapes ets. Regular trapping of rodents and bats in cocoa plots resulted in cost benefit ratio of about 1:500 in plantations near Kasaragod, increasing the productivity by more than ten times per ha.

Forest plantations

In Rajasthan (North India), due to debarking of stems and roots of important trees like Albizzia lebbek, Prosopis cineraria and Acacia tortilis by rodents (mainly Cutch rock rat, Rattus c. cutchicus), heavy mortality amoung plants is observed (Prakash, 1975). Similar damages were also observed in A. tortalis plantations in Jaisalmer and in P. juliflora in Great Renn of Cutch (Prakash, 1977) in Gujarat state. Treatment with Zinc Phosphide 2%) could reduce rodent population by about 88 percent in two years.

Grasslands and Fodder crops

Nine rodent species with preponderance of gerbils, infest grasslands in the Western Rajasthan

biome (Advani 1982c). In monsoon season, rodents damage inflorencence. They feed upon stems, seeds and roots of the predominant grasses (Cenchrus spp., Lasiurus sindicus) grown for livestock, causing great loss in the productivity of grasslands and in turn affect the milk production of region, which is source of income for about 50 percent of the inhabitants of arid zone. The annual forage feed requirements of gerbils at the density of 400 to 470/hectare, is about 1,040 kg/ha compared with an annual forage production of this range land of only 1,210 kg/ha. (Prakash, 1977).

Soil erosion and desertification

The extensive burrow systems of the desert gerbils and murids as well as their high numbers (14,000/100x100m plot), is a great danger for soil conservation in Rajasthan. By tunnelling the gerbils excavate 61,500 kg soil in a day per km^2 in crop fields and 10,43,800 kg soil/day/km^2 in uncultivated lands (Sharma and Joshi, 1975). Thus they uproot seeds of almost all cereal and vegetable crops.

Destruction to other crops and storage

The results of some studies conducted in a small area for a short term period are tabulated in the Table (1). Under storage conditions in rural complexes in Rajasthan, regular six monthly rodent trapping and control work resulted in saving of grains worth of Rs. 220 when only one rupee was spent (Prakash et al 1981).

Table 1.--Rodent damage to various crops: results compiled on the basis of short term studies in India

Crop	Damage propensity	Source
Cotton	57%	Panchabhavi and Thimmiah 1975
Groundnut	1-4% 12-31 kg/acre	Srivastava, 1966 Bindra & Sagar, 1968
Coconut	3-17%	Srivastava, 1966
Betel nut	20%	Valsala, 1958
Sugarcane	65-97 kg/ha loss 66.50 Rs/ha	Bindra and Sagar, 1968 Gupta et al 1971.
Tea bushes	upto 50% (roots)	Veeraraghavan, 1966
Barley	3-12%	Srivastava, 1968
Paddy	6-9% 1,400 kg (Storage)	Srivastava, 1968 Spillett, 1968
Sorghum	6%	Srivastava, 1966

Rodent pest management by predators

In regulating the rodent numbers predators play an important decisive role. However, parallel annual breeding cycles and reproduction capability of predators decide their effectiveness in controlling rodents. Reptiles, birds and mammals are some of the major vertebrates predating upon rodents in India. In North India, two species of lizards, Varanus bengalensis and V. griseus konieczyni are bigger and powerful as well as fast running reptiles to manage the rodent populations on the ground as well as trees. However, due to their diurnal activity patterns, they can only predate upon diurnal rodents like Indian desert gerbil, Meriones hurrianae, Bush rat, Golunda ellioti gujerati and the Indian palm squirrel, Funambulus pennanti. F. pennanti remains were collected in the stomach contents along with birds, lizards, fishes, beetles, crabs and snakes (Minton, 1966).

Snakes have been found to be promising agents in regulating the rodent numbers to a certain extent (Whitaker and Advani, 1983). Prakash (1962) listed some snake predators as the Rat snake, Ptyas mucosus; the Earth snake, Lytorhynchus paradoxus; five species of Coluber; the Sand snakes, Eryx johni, E. conicus; the Kraits, Bungarus caeruleus, B. sindanum, the Cobra, Naja naja and the Viper, Echis carinata. In addition to these, Minton (1966) reported that Sphalerosphis archarius also feeds upon the rodents. Whereas, Whitaker and Bhaskar (1978) found that Pythons regulate rat populations effectively.

Among birds, recently Jain and Advani (1982) found that about 66 percent of the fecal contents of owl, Athene brama had remains (bones, skulls, hairs etc) of Mus spp. on an yearly basis. Shikra, Accipitar badius; Tawny eagle, Aquila rapax, Merlin, Falco chicquera and Kestrel Falco tinnunculus are some of other bird species feeding upon rodents (Prakash 1975).

Predation by mammals like Long-eared hedge hog, Hemiechinus auritus collaris (krishna and Prakash 1960), the Indian false vampire bat, Megaderma lyra lyra (Advani, 1981; Advani and Makwana 1981). Asiatic jackal, canis aureus; foxex, Vulpes bengalensis and V. vulpus pusilla; Jungle cats, Felis libyca and F. chaus prateri and mongoose, Herpestes edwaraii are known to regulate rodent populations to some extent (Prakash, 1975).

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Involving the Public in Prairie Dog Management on the Nebraska National Forest[1]

George Probasco[2]

Scoping is the formal name for a process designed to identify public issues and incorporate public values into the decision making process for management of public lands. Scoping ensures that a public agency, in this case the Nebraska National Forest, will identify important issues and develop alternative management strategies for projects in full public view. Scoping has specific and fairly limited objectives: (a) to identify the affected public and agency concerns; (b) to facilitate an efficient analysis of the environmental impacts; (c) to define the issues and alternatives that will be examined in detail; and (d) to make sure that the analysis and documentation adequately address the relevant issues. Scoping should lay a firm foundation for the agency decision making process. If all the necessary information for formulating policies and making rational choices has been considered then the agency will be able to make sound and prompt decisions that will usually satisfy the public.

The scoping process began on the Nebraska National Forest when the Prairie Dog Management Interdisciplinary Team (ID Team) was appointed by the Forest Supervisor. The ID Team reviewed existing information obtained through previous public involvement efforts for earlier management decisions. Following this analysis the Team then put together a brochure for distribution to the public in order to gain further input about prairie dog management on the Nebraska National Forest. The brochure was titled "Issue Identification for Prairie Dog Management." It was mailed out in September 1986 and comments were due in the Supervisor's Office by December 1, 1986.

Over 200 documents containing comments about prairie dog management were received by the Forest. Comments were received from a wide variety of people with the following affiliations: academic/extension, business/industry, concerned citizen, environmentalist, government (local, State, and Federal), grazing permittee, grazing association, landowner, natural resource group, professional society, prairie dog shooter, and others.

The ID Team spent several weeks during the months of December 1986, January and February 1987, analyzing and summarizing the public response to the brochure. The first step in the process was to go through all the response documents (response forms, letters, documented telephone calls or conversations, petitions) line by line and highlight all the opinions and values, along with the underlying reasons. Following that the ID Team went through the comments again and looked for similar themes among those comments. Comments with similar themes were then grouped into a category defined by the subject matter of the comments. The first grouping yielded 35 individual subject categories. The Team then reviewed the categories to see if some could be combined further. This second grouping yielded 24 categories. I have chosen six of the high interest categories to discuss at this workshop.

DISTRIBUTION AND MANAGEMENT OF ACTIVE PRAIRIE DOG COLONIES

One common opinion is that prairie dog colonies on public land should not be located close to private lands. Another opinion is that prairie dog colonies should be placed in areas unsuited for livestock grazing or where there will be minimum impact on livestock grazing. Other opinions dealing with the distribution of active colonies differ because some people think active colonies should be consolidated in specific areas while others think active colonies should be scattered out more. The thought was also offered that it is impossible to maintain a specified size and distribution of active colonies. Some people also think that active colonies should be treated periodically to control overcrowding; however, another opinion questions whether treating the perimeter of an active colony will decrease prairie dog dispersal or slow colony expansion. There was one suggestion for establishing a large prairie dog area between the Badlands National Park and the White River, then eliminate prairie dogs elsewhere.

COST-EFFECTIVENESS OF PRAIRIE DOG MANAGEMENT

Opinions for this subject were so numerous and varied that subcategories were created to adequately descibe it.

Cost and Benefits

There was concern that the costs and benefits of managing or maintaining a prairie dog population are not being thoroughly and accurately evaluated. There was also concern that a cost-benefit analysis should be conducted for different levels of prairie dog populations.

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[1] Talk presented at the 8th Great Plains Damage Control Workshop. (Rapid City, SD, April 28-30, 1987).

[2] George Probasco is Assistant Planner, U.S. Forest Service, Chadron, NE.

Cost-effectiveness

There were many, varied opinions dealing with cost-effectiveness. These comments range from cost-effectiveness of the prairie dog management program to specific parts of the management program such as range management, rodenticides, and shooting.

Comments ranged from what it costs the public to retain active prairie dog colonies, to how costly it is to control prairie dog colonies through vegetation manipulation, to the cost of rodenticides, to how money could be saved by cutting out black-footed ferret surveys.

Economic Analysis

The concern here was that economic analysis be conducted by qualified economists using scientific techniques.

Benefits

The opinion was advanced that the value of prairie dog shooting to the economy, if properly managed, is equal to that of livestock grazing.

Social and Economic Impacts of Black-footed Ferret Re-introduction

Comment was made that the full social and economical impacts of black-footed ferret re-introduction need to be disclosed.

EFFECTIVENESS OF LIVESTOCK GRAZING PRACTICES IN CONTROLLING PRAIRIE DOG POPULATIONS

Opinions for this subject ranged from believing that range management practices don't help control prairie dog populations to believing that range management practices will control prairie dog populations.

PRAIRIE DOG SHOOTING

The opinions for this subject ranged from using shooting to control prairie dog populations to not using shooting since it will not control prairie dog populations. Other comments were that recreational shooting should be encouraged and prairie dog populations increased to support this use while others believe that the present prairie dog population is adequate for sport shooting.

USE OF RODENTICIDES

Opinions for this subject ranged from the need to eliminate the use of rodenticides to the need to use rodenticides since that is the only proven method of prairie dog control.

THREATENED AND ENDANGERED SPECIES CONSIDERATIONS

The opinions for this subject ranged from the need to manage for black-footed ferret habitat to the need not to worry about black-footed ferret habitat since one has not been seen for 10 to 15 years and there are none in the area.

Information gained from this public involvement effort will be used in formulating a set of alternatives to deal with prairie dog management on the Nebraska National Forest. The environmental effects of these alternatives will be estimated and the results presented to the Forest Management Team. This Team will evaluate the alternatives based on the estimated effects and select a preferred alternative. This preferred alternative will be released to the public for final review and comment. Following this final review by the public, the proposed management direction contained in the preferred alternative will be added to the Forest Plan by amending it. That management direction will be the guide for managing prairie dogs on the Nebraska National Forest for the next ten to fifteen years.

Legislative Review of Prairie Dog Statutes[1]

Lyndell Peterson[2]

If I follow my normal pattern in pursuing this subject I will probably make at least half of you mad before the afternoon is over. Within that framework I am going to share with you one of my wife's viewpoints, and that is anger is not a true emotion. You're angry either because you are ashamed or afraid or something, you aren't just mad because you want to be mad.

To philosophize for just a bit before I get into some details about legislation, one of the things I want to share with you is this: Regardless of what you think about your role in life, one of the things that makes it possible for you to be here in the condition that you are in is the fact that man pursues an activity that is designed to imbalance nature in his favor. So, no matter how much of a purist you may think you are, you have benefited from some of that activity--so don't forget it. The other thing I want to share with you is that you are here because we have a system of government that provides for values to have money allocated for supporting them, giving many of you a job. I had a similar job when I was a county extension agent. But if you fail to recognize that, then just reflect back on whatever perception you have of the evolution of mankind and think about the time when your ancestors were sitting around in a cave grunting at each other and chasing their dinner with a stick. When they got to where they could not catch any more dinner, they moved their territory and might run into another group of people who thought that was their territory. And the first thing you know, you either had a war or you figured out a way to get along.

The legislature is a modern version of a system that allows us to get along and bring our values together, sort them out, and establish ground rules under which we function. As we imbalance nature in our favor and apply our values through the legislature and congress, one prevailing value is that most of us will go to war for our right to own property. Yet there are times when our point of view functions in such a way that we say this process should provide us authority and power over somebody else's property as long as nobody exercises that same authority over ours. My philosophy is that you should not seek from government any power over another person that you do not wish to abide by yourself. Within that framework then, one of the principles I have applied in the legislative process is that everybody in a democratic society is entitled to access that system. In other words, one's point of view, idea, value is entitled to be injected into the legislative system; and, I have faith enough here in South Dakota that the 105 people who meet every year represent enough of our societal values so that the right answer will come out.

It is on that basis then that I function; this consistently has caused Game and Fish people, Forest Service people, Fish and Wildlife people, and others to regard me as their enemy. At the same time, it turns out that there are some private landowners trying to make a living from the imbalancing of nature on that land who think, "By golly, Peterson is all right." There are others who, because maybe they think they have risen above this process of imbalancing nature in their favor, take off from a very safe vantage point, because they have nothing to risk, and criticize the people I am trying to represent.

During my time in the legislature (my first session started in 1977) I have been a sponsor of or have generated amendments on legislation dealing with a number of subjects that related to the subject we are talking about here today. The first was an amendment to the Endangered Species Act of South Dakota that (1) took out the right of the Game and Fish Department to acquire land and aquatic habitat for endangered species; (2) put in a provision that the Game and Fish Department has a responsibility to control prairie dogs on private land adjacent to public lands when the infestation is coming from public lands to private lands; and (3) specified that control should be done at no cost to the landowner. The Game and Fish attorney at that time just about went through the roof of the Capitol Building. When he accosted me in the hall after that amendment was adopted he said, "What in the hell do you think you are doing? Do you realize you just cost us a million dollars?" And I said, "Who in the hell do you think has been paying the bill up to now?" The private landowner who happens to be unfortunate enough to live next to Badlands National Park or other federal lands that are being managed for something other than making a living. Well, that little amendment stayed on and it is a part of South Dakota law.

Later on I got involved with Jon Sharps here and his Vulpes velox--the swift fox. It happened we were on friendly terms in that situation. We were trying to make it possible for a situation to develop whereby Jon and ranchers working together could attempt to establish some swift fox in prairie dog areas. I might tell you that that is where the breeding stock for his poodles came from, but be

[1]Talk presented at the 8th Great Plains Damage Control Workshop. (Rapid City, SD, April 28-30, 1987).

[2]Lyndell Peterson is a South Dakota State Senator, Rapid City, SD.

that as it may. Did we get that legislation through, Jon? No, not entirely. We did not get into business. The citizens expected some results from the initial amendment, and it was not happening. In order to move the Game and Fish outfit forward a little bit--I think it was the next year--we put an amendment on the bounty bill for predators, and I think South Dakota is the only state in the nation where prairie dogs are listed as predators. But that tied them together with the money that was being spent on predator control, and the first thing you know we had Game and Fish people out there working with private landowners to control prairie dogs when they were coming over from the park and different places.

Then, as we moved along we adopted the State Weed and Pest Law, which Dennis Clarke will talk about, and that kind of brought prairie dogs in. We had an old law on prairie dogs that nobody used, but it allowed for forming prairie dog control districts with the new Weed and Pest Law now in place.

The most recent legislation was passed this year, this session; it separated the two components and viewed the relationship of county weed and pest boards to federal land. And, in those cases where noxious weeds or pests existed on federal lands but the weed and pest board could not get cooperation from the land management agency, the Weed and Pest Board could automatically refer the enforcement notice to the State Attorney General, who could deal with the federal land manager. The idea behind that is that somewhere along the line private citizens who essentially volunteer to serve on a weed and pest board should not spend their money to fight the government. The government ought to be the people who are performing up to the letter of the law rather than be the problem, as it is in some cases. In all of this legislation up to now, with the exception of the Weed and Pest Law adoption, there has always been a polarization of people in such a way that somebody managed to interpret what was being done as though all of Mother Nature was being raped and somebody was throwing down the entire value system of our country and was tearing us apart. It has been an interesting process, and I do not think we have wrecked anything too badly yet.

Politics, Prairie Dogs, and the Sportsman[1]

Jon Sharps[2]

I would like to speak to you today about potential economic and biological values of prairie dogs. When I refer to prairie dogs throughout my talk, I'm referring only to the prairie dogs on the National Grasslands Systems in western South Dakota. Prairie dogs have great economic potential to sportsmen and the general public and also act as ecosystem regulators to grassland plant and animal communities, and as such, could enhance both potentials if managed differently.

According to South Dakota Department of Game, Fish and Parks, sportsmen spent about 46,000 hunter days shooting prairie dogs in western South Dakota last year; and I might add, this is a conservative estimate. Sportsmen spent an estimated average of $70 a day for a total of about 3.2 million dollars which was returned to the general economy. In addition, prairie dogs on the biological side are extremely important because they provide habitat for a host of avian and mammalian prey and predator species.

In 1978 the Forest Service and the Department of Game, Fish and Parks embarked on a campaign to virtually eliminate the prairie dogs from the National Grasslands. The Wall Ranger District and the Fall River Ranger District bore the brunt of this campaign. This decision was political and was brought about by the complaints of livestock permittees to the Forest Supervisor, State Legislature and to the Secretary of the Department of Game, Fish and Parks. The result of that campaign is the current Prairie Dog Management Plan. In my opinion, this decision and resultant plan was and is wrong when one considers that the permittee's represent only 2% of the livestock industry in South Dakota.

When one weighs the economic and biological values of prairie dogs against livestock grazing --which, I might add, is only one aspect of the approved multiple use concept on the grasslands--one is hard put to find justification for the large-scale reduction of prairie dog towns that took place. For example, in 1978 there were approximately 43,000 acres of prairie dog towns on the Buffalo Gap National Grasslands. This is roughly equal to about 6% of those grasslands. Currently there are only about 4,200 acres of dog towns remaining, which amounts to a 90% reduction from that 1978 level. This roughly equates to about 0.2% of prairie dog towns left on National Grasslands.

Subsequent studies have shown that assumptions made by land and wildlife managers and the political advocates of prairie dog annihilation were wrong. Those assumptions were that if you got rid of the prairie dogs you would increase forage and livestock production. Let me give you some examples. It takes around 300 prairie dogs to consume as much forage as one, 1,000-pound cow, which is somewhere around 32 pounds of forage a day. If you were to eliminate all prairie dogs from a grazing area you would only gain about 4.4% to 8% more forage for livestock, which would not be biologically or economically feasible.

In looking further into the economics of prairie dog control, it has been found that it costs approximately $17 per acre, or around $3 per prairie dog, to get them poisoned. These figures are from an ongoing control program on the Pine Ridge Indian Reservation. They are using zinc phosphide as a control agent, and the overall cost of that program is $6.2 million and is scheduled to run five years. All things considered, I do not believe it will be economically justifiable when you consider prairie dogs repopulate at about a 30% annual rate; at least they have in the initial control area. You will have to treat the area every three years or so to maintain that kill ratio. This is with a 95% kill ratio using zinc phosphide. Studies have also shown that controlling prairie dogs did not increase forage produced whether or not cattle were allowed to graze. Results indicated that reduced livestock grazing may be required to increase forage production. It is well known and documented that prairie dogs are more abundant in areas heavily grazed by cattle than in areas where cattle are excluded. Further, plant production has increased more on areas grazed by prairie dogs only than by cattle plus prairie dogs.

All the evidence I have been able to gather suggests sportsmen and the general public have been sold a bill of goods regarding the current philosophy of prairie dog management. The cost ratio of control programs does not equate when compared to potential economic and biological benefits. This is particularly true when you consider that the primary benefactor of the current control program is the livestock permittee and the loser is the general public to whom the land belongs. The sportsman segment of the general public is the greatest loser along with the small businessman who depends on the sportsman's dollars as a part of his living. Another big loser because of the current management

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[1]Talk presented at the 8th Great Plains Damage Control Workshop. (Rapid City, SD, April 28-30, 1987).

[2]Jon Sharps is Owner of A-1 Kennels, Boxelder, SD.

system is the wildlife ecosystem. Very little consideration is given to state and federally listed endangered species in my opinion. Indeed, one gets the impression they hope no endangered species will be found because it might upset the management system.

As a true part of the multiple use concept as described in the Forest Plan and by the various laws and rules authorizing that plan, I believe prairie dog towns could be increased to provide for recreation and enjoyment of the general public without harming the livestock industry. I would suggest a minimum increase of 1.8% of prairie dog towns which could be located equally throughout the Grasslands System or where the public can have easy access to them. Biological considerations for other species should also be considered in this increase. This increased level would provide around 13,000 acres of prairie dog towns and would bring in around $4.2 million annually to the general South Dakota economy, again assuming that $70 per day are spent by sportsmen. I believe it is past time to recognize and manage the prairie dog for all the valuable parts it plays in the ecological scheme of things. And it is certainly past time to stop foolishly spending our tax and sportsmen's dollars on a program designed to make us all lose.

Prairie Dog Control—A Regulatory Viewpoint

Dennis C. Clarke

Prairie dogs and their control are complex issues. At this conference we've heard numerous speakers discuss a wide variety of topics concerning the organism's effect on range and man's attempts to deal with those effects. It appears one could make a case for or against the prairie dog depending on his own particular situation and experience. While the organism is a natural part of the prairie ecosystem, it may not be a desirable inhabitant of a livestock producers range when its population goes unchecked.

This leads to conflict. The prairie dog becomes a biopolitical issue. On one hand it evolved with the prairie ecosystem, as have grasshoppers, but when it competes too directly for a resource man needs to support his portion of the food chain, it may become an unwelcome member of a particular grassland community. Regulation of its populations may be necessary. It is my assignment, in the next few minutes to discuss the philosophy and mechanism we in South Dakota use to accomplish this end.

Whenever an introduced or endemic plant or animal species that has the potential to cause economic loss inhabits land to the degree that it poses a threat to the infested land itself, neighboring lands or the resource as a whole, it becomes a concern of society in general. The offending plant or animal may need to be controlled to reduce or remove the threat. Most landowners and managers are good stewards of the land. They recognize organisms that have the potential to adversely affect their land's productivity. They further recognize that even if their own personal value system allows for the presence of what many people feel are undesirable plants or animals, they must control them to keep from imposing their values on those held by society as a whole.

Unfortunately, not everyone acts in a manner felt to be indicative of a good steward of the land. Society has long recognized this. It has passed laws that require the control of plants and animals that have the potential to cause adverse economic impact and/or general resource deterioration even if a landowner is not so inclined. These laws are in force in some form or another in virtually every state in the nation and, we can probably say, every country in the world. Only the plants and animals that are regulated and the method of obtaining compliance with the regulatory requirements varies from place to place.

Normally legislation that allows society to control undesirable organisms does so by declaring them a public nuisance. Commonly the statutes involved outline the criteria for determining what organisms are considered to be nuisance candidates and the procedure to be followed in controlling offending infestations. Often times plant and animal control requirements are in different statutes. South Dakota has seen fit to combine the regulatory mechanisms for both in one law. The state's present Weed and Pest Statute was enacted in 1983. As written, the statute enables County Weed & Pest Boards, with direction from the State Weed & Pest Control Commission and coordination and assistance from the State Department of Agriculture, to take action to control nongame birds, insects, and rodents - pests - in a systematic, organized manner.

One of the Commission's first orders of business after the legislation went into effect in January, 1984, was to designate prairie dogs as a statewide pest, an action that was clearly part of the intent of the state legislature.

This action was felt necessary because prairie dog populations had expanded during the mid and late 1970's to the point where an estimated 730,000 acres were infested, covering about 3% of the state's hay, range, and pasture lands. This infestation level was estimated to be costing producers about 3.5 million dollars annually in direct losses and a total of nearly 10 million dollars when both direct and indirect losses were considered.

Clearly action was needed to check the spread of prairie dogs and decrease their effect in areas where they had virtually taken over large tracts of range.

Since the early 1980's a combination of factors have been effective in reducing the infested acreage. Federal and state agencies became active on lands they control. At the same time, counties using the Weed and Pest Boards as a local coordinating and regulatory base, organized programs and educated landowners in control techniques. County Boards have used resources available through the Cooperative Extension Service, Animal Damage Control and the Department of Agriculture to assist with building viable control programs. These efforts have reduced the prairie dog infestation level to what we estimate is about 200,000-250,000 acres that have not been treated.

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[1] Talk presented at the 8th Great Plains Damage Control Workshop. (Rapid City, SD, April 28-30, 1987).

[2] Dr. Dennis C. Clark is State Weed and Pest Coordinator, South Dakota Dept. of Agriculture, Pierre, SD.

To motivate landowners who have not responded to educational and voluntary control requests many of the County Weed and Pest Boards are now entering the enforcement phase of prairie dog control programs. The State Weed & Pest Control Commission defines control to mean that an infestation has been treated so that it no longer poses a threat to neighboring lands. It does not mean eradication.

To "force" control, two avenues are available to a county:

1. Protective operation = state enforcement.
2. Remedial action = county enforcement.

Both processes are similar in mechanics. Statutory language ensures that landowners receive due process through notification of control requirements and specific time allowances for voluntary compliance with written control orders. Only after results have not been forthcoming through initial enforcement steps do county boards or the Department of Agriculture have the authority to control an infestation at the landowner's expense.

If you are interested in the actual mechanics of an enforcement, I would be most happy to discuss it with you at some other time. At this point, suffice it to say, the system has been effective and met the need of controlling prairie dogs in some instances where it was determined to be in the best interest of protecting the resource and the rights of adjoining landowners.

A Chronology of Prairie Dog Control Operations and Related Developments in South Dakota[1]

Rew Hanson[2]

The black-tailed prairie dog is a South Dakota native with a long history of controversy regarding its activities and control. The first organized efforts in prairie dog control date back to 1914 but little information was recorded until 1919 with some county operations and the passing of a rodent control law by the South Dakota Legislature. Nine west river counties reported treating a total of 398,000 acres of prairie dogs in 1920.

These early programs were organized on a county by county basis involving the board of county commissioners, the county agent and the Bureau of Biological Survey, USDA. The county had the option of purchasing strychnine oat bait at $8 per bushel FOB Minneapolis or mixing their own strychnine oat bait according to the Bureau's formula for about $4 per bushel. It was also their option to contract or hire crews to do the baiting or to set up cooperative or community programs where individuals did their own baiting. In either case, the Bureau provided training, direction and demonstrations on bait preparation, application procedures and other technical aspects of control. After implementation, the supervision of the project was usually delegated to the county agent who became the key figure in that control effort.

A summary of prairie dog control programs conducted in the five counties of Haakon, Fall River, Pennington, Jackson, and Butte during 1922 provides some fiscal perspective. Approximately 150,000 acres were poisoned for the first time and some 20,000 acres were repoisoned for a total of 170,000 acres. They used 1255 bushels of strychnine oat bait at $4.00 per bushel which amounts to $5,020. The average applicator baited 75 acres of infested land per day and his labor was worth $3 per day or 4¢ per acre. Labor costs for the 170,000 acres were $6,810 plus bait at $5,020 for a total of $11,830 or about 7¢ per acre. Carbon bisulphide was sometimes used in cleanup and its cost was figured at 1¢ per burrow treated.

This same year, 1922, a Reservation wide survey on the Pine Ridge Indian Reservation indicated at least 140,000 acres of prairie dogs. Organized prairie dog control programs continued through the twenties on private, state, federal and Indian lands and by 1930 the prairie dog population had been reduced to widely scattered small towns.

Also in 1930, the Bureau of Biological Survey moved its offices from Rapid City to Mitchell and established the first central bait mixing plant. Hard times and the dust bowl of the thirties saw these small prairie dog populations grow large. Organized prairie dog control programs, utilizing some of the Federal emergency work programs during the thirties, were successful in achieving control once more. This overall effort probably had prairie dog populations at the lowest level to date.

By 1940, the prairie dog population in South Dakota had again reached a stage where colonies were small and usually consisted of a few acres each. Also in 1940 the Bureau of Biological Survey was transferred from the Department of Agriculture to the Department of Interior and became the Fish and Wildlife Service. By 1945, there had been a general increase in prairie dog infestations throughout the District (North Dakota, South Dakota and Nebraska).

By 1950, operational use of 1080 oats under the direct supervision of Predator and Rodent Control personnel was the standard prairie dog control procedure, although strychnine bait was still used by many private landowners. From the late forties to the mid fifties, 20,000 to 50,000 acres per year were treated.

From 1955 to 1965, prairie dog populations were kept at management levels. In 1965 some 25,000 acres were treated and the policy on pre-control surveys for black-footed ferrets was established. From 1965 to 1971, up to 31,000 acres were treated per year and in 1968, prairie dog acreage in South Dakota was estimated at 61,000 acres.

In 1972, Executive Order #11643, in effect stopped the use of toxicants on federal lands and by federally funded programs. Prairie dog control efforts were on hold through 1975. In 1973, a questionnaire to land owners and operators on the Pine Ridge Indian Reservation indicated some 32,000 acres of prairie dogs.

In 1976, zinc phosphide oats became the prescribed prairie dog bait for use on federal lands and in federal programs, and some 30,000 acres were treated per year through 1979. The South Dakota Department of Agriculture reported 730,000 acres of prairie dogs in the state in 1980. In 1981, the prairie dog acreage on the Pine Ridge Indian Reservation peaked at near 300,000 acres.

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[1]Talk presented at the 8th Great Plains Damage Control Workshop. (Rapid City, SD, April 28-30, 1987).

[2]Hanson is State Director of APHIS, ADC, Pierre, SD.

During the years 1980 through 1984, a total of 997,000 acres were baited in South Dakota. 464,000 of these acres were on the Pine Ridge Indian Reservation. During 1985 and 1986, 329,000 acres were baited in South Dakota and 240,000 of these acres were on the Pine Ridge Indian Reservation.

A recap of the 85 and 86 control programs on the Pine Ridge Indian Reservation show that operational costs averaged $6.90 per acre for the two year period. Pre-control surveys for black-footed ferrets came to $0.98 per acre which brings the total field cost to $7.88 per acre. Except for one zone of some 5,000 acres that did not get baited properly in 1986, the degree of control achieved for the two years averaged over 92%.

Recommended criteria for efficient and consistent control of Prairie dogs: Allow at least 2 years since the last baiting. September and October is the prime time for baiting in South Dakota but can be August to November. Use good quality bait and pre-bait. Exercise proper application, 1 heaping teaspoonful splashed on firm, bare soil at each mound. Do not exceed 10 days between pre-bait and baiting. Require that 95% or more of the mounds are baited. Minimize disturbances after baiting. Keep control areas blocked together. Coordinate control efforts with adjacent areas.

Carbonbisulphide, calcium cyanide, gas cartridges, and aluminum phosphide are fumigants that have been used for cleanup. Gas cartridges and aluminum phosphide are currently registered for such use. Spring is the recommended period of use due to the desirable soil moisture level and that the prairie dogs are concentrated in the fewest burrows. The use of fumigants represent the most labor intensive and the most expensive control tool.

In the long term, range management is critical. Good to excellent range provides the best protection from prairie dogs and the best return to the owner.

We have seen elevated prairie dog populations in South Dakota about every 15 years from 1920 to 1980, separated by intervening lows. We are now approaching the ensuing low. I am sure you recognize the many social, economic, political, biological and climatic conditions that have influenced these fluctuations, but I think Noble Buell, a former District Agent here in South Dakota got to the heart of it when he said "As control succeeds, human concern diminishes, therefore, control is self limiting."

Endangered Species Considerations in Prairie Dog Management[1]

Max Schroeder[2]

Past management of the prairie dog has more often than not resulted in the reduction of prairie dog ecosystems upon which one endangered species, the black-footed ferret, depends. This species and over 400 other species found in the United States and its Territories are currently protected by the Endangered Species Act. The current Endangered Species Act had its start in 1964. At that time, the Bureau of Sport Fisheries and Wildlife selected a committee of individuals to determine which animal species in the United States were threatened or endangered with extinction. These individuals, with the help of some 300 other persons and organizations, compiled the first tentative list of rare and endangered wildlife. The black-footed ferret was listed at that time as one of 135 endangered species. In June 1965, the ferret was accorded protection by the Assistant Secretary for the Fish and Wildlife Service, through a policy that recognized the black-footed ferret as an endangered species closely associated with and believed dependent on the prairie dog for food and shelter. This policy stated that while the Department of the Interior has a responsibility for protecting the black-footed ferret, it was also responsible for the control of animals that were considered significantly detrimental to the best interest of man.

To satisfy these responsibilities, protecting the ferret and suppressing prairie dogs, the policy required that before any toxic bait was made available for prairie dog control by the Bureau of Sport Fisheries and Wildlife, the Bureau would conduct investigations of any prairie dog towns proposed to be treated to determine that they were not at that time occupied by black-footed ferrets. The first systematic surveys done in response to the policy were conducted by the Fish and Wildlife Service in August 1965 on the Pine Ridge Indian Reservation in South Dakota. This first policy was followed in 1966 by the Endangered Species Preservation Act which directed the Secretary of the Interior to carry out a program to protect, restore, and propagate selected species of native fish and wildlife. This was followed in 1969 by the Endangered Species Conservation Act. This act expanded the land acquisition authority of the 1966 act, better defined the authorities granted in the 1966 act, and authorized the Secretary to develop a list of species subject to extinction.

[1]Talk presented at the 8th Great Plains Damage Control Workshop. (Rapid City, SD, April 28-30, 1987).

[2]Max Schroeder is Black-footed Ferret Coordinator, U.S. Fish & Wildlife Service, Denver, CO.

In 1973, the current Endangered Species Act was enacted. This is a much stronger and more comprehensive statute than either the 1966 or 1969 documents. This Act has been amended several times, including the most recent amendment in 1982, and directs the Secretaries of the Interior and Commerce to, among other things, develop a list of species that are in danger of extinction and to carry out programs for the conservation of listed species. The Secretary of Commerce delegated this authority to the National Marine Fisheries Service, which is responsible for the list of marine species when they are at sea. The Secretary of the Interior has delegated the authority for marine species when on shore and all other listed species to the Fish and Wildlife Service. Programs for the conservation of listed agencies include provisions to provide a means to conserve the ecosystem upon which the endangered and threatened species depend; to take appropriate steps to achieve the goals of the various treaties and conventions listed within Section 2(a) of the Act; and to encourage the States and other interested parties to develop and maintain conservation programs that meet national and international standards. Several sections of the Act have special considerations for endangered species recovery. These could impact prairie dog management, since prairie dogs are the major prey species of the endangered black-footed ferret.

Section 4 of the Act directs the Fish and Wildlife Service to determine whether a species is endangered or threatened because of any of several factors. Some of these include present or threatened destruction, modification, and curtailment of habitat or range; overutilization of a species for commercial, sporting, recreational, scientific, or educational purposes; the effects of disease or predation upon the species; the inadequacies of existing regulatory mechanisms for the species, or other natural or manmade factors that may affect its continued existence. Within this section is a mechanism for (1) listing the various species subject to endangerment throughout the world, and (2) also developing recovery plans for each listed species.

Section 6 of the Endangered Species Act provides that the Fish and Wildlife Service may enter into a cooperative agreement with a State agency to conserve resident endangered species. The Service may enter into a cooperative agreement with any State which establishes and maintains an adequate and active program for the conservation of any endangered or threatened species. Through Section 6 agreements, the Service is authorized to provide financial assistance and to assist States in the de-

velopment of programs for the conservation of endangered or threatened species.

Section 7 is interesting when considering the management of prairie dogs. Section 7(a)(1) of the Act states that the Service and all Federal agencies shall utilize their authorities to carry out programs for the conservation of endangered or threatened species. Section 7(a)(2) further requires that Federal agencies, in consultation with and without the assistance of the Service, ensure that any action that they authorize, fund, or carry out is not likely to jeopardize the continued existence of any endangered or threatened species, or result in the destruction or adverse modification of a species' critical habitat. If a Federal agency plans any activity in an area involving prairie dog habitat, that agency should contact the Service's field office that is responsible for the site on which they plan the activity. If the Service informs the agency that black-footed ferrets could occur in the project area, then surveys for black-footed ferrets may be necessary. These surveys would be carried out by the agency proposing the action.

Standardized survey techniques and data that are gathered on each project site, draft black-footed ferret survey guidelines for compliance with the Endangered Species Act. These guidelines are currently being used by the Fish and Wildlife Service field offices in Grand Island, Nebraska; Salt Lake City, Utah; Grand Junction, Colorado; Helena, Montana; and Region 2 in Albuquerque, New Mexico. These surveys are used to aid Federal agencies to ensure that no actions that they fund, authorize, or carry out are likely to jeopardize the continued existence of the black-footed ferret.

Duck Nest Success and Predators in North Dakota, South Dakota, and Montana: The Central Flyway Study[1]

Michael A. Johnson, Thomas C. Hinz, and Thomas L. Kuck[2]

Abstract.--Data on duck nest success and the distribution and abundance of nest predators were obtained from nine study areas in North Dakota, South Dakota and Montana. Success rates were extremely low due to predation and duck production over much of the region may be insufficient to maintain populations.

INTRODUCTION

Numerous studies during the past 20 years have produced estimates of duck nest success in the Prairie Pothole Region (PPR) of the United States. Recently, Northern Prairie Wildlife Research Center (NPWRC) compiled data from many of these studies into a 15,000-record database for use in a mallard (Anas platyrhyncos) recruitment model (Cowardin et al. 1983 and Johnson et al. 1986). This model is designed to allow managers to evaluate the effectiveness of various management options for improving mallard recruitment. However, two major deficiencies exist in the data base (Klett et al. in press). Although most ducks (>90%) in the PPR nest on private lands (Hochbaum and Bossenmaier 1965, and Cowardin and Johnson 1983[3]), most studies contributing to the data base were conducted on public lands managed for wildlife production. Also, most of the data were obtained from relatively few study areas and there is little comparable information for large portions of the Dakota's and Montana (Klett et al. in press). Additionally, although predation is a major factor limiting duck nest success (Cowardin 1985), few nesting studies have produced concurrent information on which to assess predator populations (Sargeant 1983)[4].

This paper presents data collected during a one-season study designed to obtain estimates of duck nest success by habitat type and estimates of predator populations for nine study areas in North Dakota, South Dakota and Montana. Emphasis was placed on obtaining nest success records for habitats not specifically managed for wildlife in areas with little or no previous duck nest data. Duck nest data were collected to improve the ability of the NPWRC Mallard Model to evaluate management alternatives for increasing duck recruitment in the Central Flyway. Both nest and predator data complement that obtained in Canada during the study of stabilized duck hunting regulations (Greenwood et al. in press).

ACKNOWLEDGEMENTS

This study was a cooperative venture which required the help and assistance of many individuals and agencies. The study was designed and directed by the Duck Recruitment Subcommittee of the Central Flyway Waterfowl Technical Committee which included H. Funk, T. Hinz, J. Hyland, M. Johnson (Chairman) T. Kuck and H. Miller. The study was jointly funded by the ten state wildlife agencies represented by the Central Flyway Council. Portions of this study were financed with Pittman-Robertson funds. The Wildlife Management Institute generously handled financial and accounting logistics. Field work was organized and conducted by the following: North Dakota Game and Fish Department, M. Johnson, D. Orthmeyer, J. Harber and D. Timpe; South Dakota Cooperative Wildlife Research Unit, R. Linder, E. Keyser, R. Libra, K. Shea, C. Olawsky, B. Wangler, M. Kintigh, D. Beck and H. Browers; Montana Cooperative Wildlife Research Unit, J. Ball, S. Sovey, R. Bennett and A. Hetrick. Carnivore track

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[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop, Rapid City, South Dakota, April 28-30, 1987.

[2]Michael A. Johnson is Supervisor, Migratory Game Bird Management, North Dakota Game & Fish Department, Bismarck. Thomas C. Hinz is Migratory Bird Biologist, Montana Department of Fish, Wildlife and Parks, Billings. Thomas L. Kuck is Regional Supervisor, Ducks Unlimited, Aberdeen, South Dakota.

[3]Cowardin, L.M. and D.H. Johnson. 1983. A predictive model to guide management or acquisition of waterfowl habitat. Unpublished report. U.S. Fish & Wildlife Service, Northern Prairie Wildlife Research Center, Jamestown, North Dakota.

[4]Sargeant, A.B. 1983. Personal communication. Northern Prairie Wildlife Research Center. Jamestown, North Dakota.

searches were conducted by U.S. Fish and Wildlife Service Animal Damage Control field personnel in Montana and North Dakota and by Game, Fish and Parks Extension Trappers in South Dakota. NPWRC, Jamestown, ND, provided much assistance, direction and equipment. L. Cowardin demonstrated the need for this work to the Central Flyway Council and Technical Committee and with D. Johnson provided guidance in study design and implementation. T. Klett and R. Greenwood developed and provided the study manuals and data forms used in the nesting study. A. Sargeant designed, helped direct and provided data analysis of the predator surveys. NPWRC keypunched the data and T. Schaffer compiled and produced computer summaries. The Office of Migratory Bird Management (FWS) provided color infrared aerial photographs of the study transects and NPWRC made black and white enlargements for use as field maps. Private landowners in all three states generously allowed study teams access to their land. Many others also provided field assistance, equipment and help. We express our sincere appreciation to all who contributed to this study.

METHODS

Data were obtained on and near nine Fish & Wildlife Service air/ground comparison transects (Martinson and Kaczynski, 1967) located in North Dakota, South Dakota and Montana (fig.1). Transects were selected because of their proximity to areas with limited duck nest success data. Each transect study area was three miles wide and ranged from 12

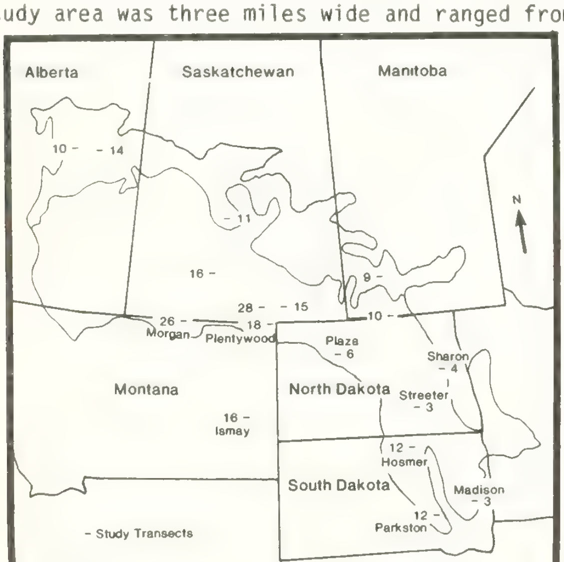

Figure 1.--The Prairie Pothole Region of the United States and Canada with locations of 1983 air/ground transect study areas and Mayfield mallard nest success estimates for South Dakota, North Dakota and Montana (this study) and Manitoba, Saskatchewan and Alberta (Greenwood 1987)[5].

to 36 miles in length. Because the Morgan and Plentywood transects in Montana lie directly on the U.S. - Canadian border all work was conducted on the southern one-half of these transects.

Field crews were instructed to find as many duck nests as possible in each of seven basic habitat types (grassland, hayland, planted cover, cropland, rights-of-way, wetlands and odd areas) during each search of each transect. Habitat classifications follow those of Cowardin et al. (1985) except for planted cover, which we defined as idled stands of grass or grass/legume mixtures such as nesting cover provided on many state and federal wildlife areas (Duebbert et al. 1981). Emphasis was placed on finding nests on private lands and habitats not specifically managed for wildlife. If specific habitat types were not present or landowner permission could not be obtained, searches were conducted on substitute areas nearby. Procedures for searches, marking nests, and determining the stage of incubation, species and nest fate followed those described by Higgins et al. (1977) and Klett et al. (1986). Odd areas such as rock piles, brush clumps or fence rows were searched on foot or (in North Dakota) with a boom-type drag mounted on an ATC.

Searches were conducted between the hours of 0600 and 1400 from May 2 through July 10. The date of first search on each transect was as follows: May 2 - Madison, Sharon, Ismay; May 9 - Hosmer, Streeter; May 16 - Parkston, Plaza; May 17 - Morgan; May 26 - Plentywood. Each transect was searched three times at approximately 21-day intervals. The Sharon transect was searched a fourth time in an attempt to find additional nests.

A nest was defined as a hollow scrape containing one or more eggs. Nest success was calculated using the Mayfield method (Klett et al. 1986) and a standard exposure period of 34 days for all species. A successful nest was one in which one or more eggs hatched. Unsuccessful nests were classified as destroyed due to predation, agricultural practices, weather or other factors or abandoned. Because of the difficulties in making a positive determination from remains at a nest, no attempt was made to identify the species of predator which destroyed a nest (Sargeant 1983)[6]. Nests not revisited to determine fate, abandoned due to investigator influence or damaged by search operations were not included in nest success calculations.

Predator species targeted for assessment on each transect were badger (Taxidea taxus), coyote (Canis latrans), Franklin's ground squirrel (Spermophilus franklinii), long-tailed weasel (Mustela frenata), raccoon (Procyon lotor), red fox (Vulpes vulpes), striped skunk (Mephitis mephitis), American crow (Corvus brachyrhynchos), and black-billed magpie (Pica pica). Surveys conducted were: 1) line transect counts of crows and magpies, 2) livetrapping of Franklin's ground squirrels, 3) carnivore track

[5]Greenwood, R.J. 1987. Personal communication. Data on file Northern Prairie Wildlife Research Center, Jamestown, ND.

[6]op. cit.

counts, and 4) recording of predator sightings. All predator data (except predator sightings) were collected on a 10 mile long predator survey area that extended one-half mile on each side of the center transect road. This area included 40 quarter-section (160 acre) sample areas. Predator sighting data was collected wherever the crews were working on or near the air/ground transects.

Line transect counts of crows and magpies were made by driving the center transect road of the predator survey portion of each study transect on at least three days of each nest search period. Stops were made at the midpoint of each quarter section sample unit to count all crows and magpies seen within a 1/8 mile half-circle radius of the vehicle during a 1-minute period. Data for two adjoining quarter section sample units (one on each side of the road) were usually obtained at each vehicle stop point. In addition to these data, investigators recorded presence or absence of each species in each quarter section sample unit as detected visually or by call, both while driving the transect road and while stopped. Most surveys were conducted during midday, after nest searching was completed, on days when weather conditions were favorable (conditions were specified).

Livetrapping of Franklin's ground squirrels was conducted in early July and consisted of setting four livetraps in each of five "best" sites with brushy or dense vegetation along each linear mile of the predator survey areas. Traps were baited with canned sardines. Trapping sites were no closer than 220 yds. from each other and traps at a site were no closer than 20 yds. from each other. Traps were set at one site along each linear mile in early morning and checked and moved to another site (at least 100 yards away) the next morning. Trapping was conducted on five consecutive days unless interrupted by bad weather in which case trapping resumed when suitable conditions returned. All ground squirrels caught were marked with dye (to determine if recaptures were made) and then released unharmed at the capture sites. Livetrapping surveys were not accomplished on the Morgan and Ismay transects.

Carnivore track counts involved an individual searching for tracks of fox, coyote, skunk, badger and raccoon on each of the 40 quarter-section sample units where trespass was permitted on each predator survey area. One search was conducted on each of the air/ground transects as time permitted during mid-May to late June. The investigators were instructed to spend up to 0.5 hour on each quarter-section sample unit examining "best" sites for tracks of each species. Investigators categorized abundance of tracks and recorded length of small and large canid tracks for reference in assessing canid track identification. Track survey data is expressed as the percent of quarter-section sample units on which tracks were observed.

Study personnel kept daily records of numbers of places on each transect where one or more individuals of specified predator species were seen. Observations made on all portions of the transects were included but most were from the 10 mi. long predator survey areas, because investigators spent most time there. All personnel working with nest search crews were asked to independently supply this information everyday they worked on a transect and to record the amount of time spent on the area and their major work activity. A place where a predator was observed was defined as a 160-yd. diameter area (about 5 acres).

RESULTS

The number of acres of each habitat type searched during all searches are shown in table 1. Because some fields were only searched once, while others were searched up to four times, the number of acres searched represents the combined total of the acres searched during all searches.

A total of 678 nests of 10 duck species was found during the study (tables 1 and 2). Nests of blue-winged teal (_Anas discors_) were most frequently found (41 percent) followed by gadwall (_A. strepera_) (19 percent), mallard (15 percent) and Northern pintail (A. acuta) (13 percent). Northern shoveler (_A. clypeata_), lesser scaup (_Aythya affinis_), American wigeon (_Anas americana_), green-winged teal (_A. crecca_), ruddy duck (_Oxyura jamaicensis_) and redhead (_Aythya americana_) comprised the remaining 15 percent of the nests found.

Thirty-eight percent of all nests were found in grassland habitats (49 percent of the acres searched) (table 1). Grassland habitats contained 57 percent of the nests in Montana (78 percent of the areas searched), 50 percent in South Dakota (43 percent of the acres searched) and 27 percent in North Dakota (25 percent of the acres searched). Planted cover which totaled only six percent of the acreage searched contained 21 percent of the nests. Although cropland comprised 20 percent of the acreage searched it contained only four percent of the nests found.

The distribution of nests among habitats by species is shown in table 2. Mallards nests were found most frequently in right-of-ways (29 percent), grassland (25 percent), and planted cover (23 percent). Most gadwall nests (41 percent) were found in planted cover. All other species (except redheads and ruddy ducks) were most common in grassland habitats. Pintails nested more frequently in cropland than any other species and less frequently in planted cover than the other dabblers.

Nest fate was determined for 625 of the 678 nests found (table 3). Overall, 72 percent of the nests did not hatch. The percent of successful nests was higher in Montana (45 percent) than in the Dakotas (24 percent each). Predation accounted for 90 percent of all unsuccessful nests with predators destroying 69 percent of the nests in each of the Dakotas and 49 percent in Montana. Predation rates were highest on the Madison transect in South Dakota (79 percent) and lowest on the Ismay transect in Montana (17 percent).

Table 1.--Number of acres searched (A) and nests found (N) by habitat type during three nest searches[1] on air/ground transects in South Dakota, North Dakota and Montana, 1983.

State and Transect	Grassland		Hayland		Planted Cover		Cropland		Other		Right-of-way		Wetland		Total	
	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N
South Dakota																
Hosmer	1,359	2	486	2	0	0	537	1	95	0	288	3	84	0	2,849	8
Madison	555	38	160	8	267	18	270	1	30	0	148	7	143	6	1,573	78
Parkston	870	41	470	11	0	0	241	3	16	5	278	12	184	4	2,059	76
Subtotal	2,784	81	1,116	21	267	18	1,048	5	141	5	714	22	411	10	6,481	162
North Dakota																
Streeter	912	30	312	9	240	21	955	7	204	26	337	30	15	1	2,975	124
Sharon	879	4	300	2	559	17	1,350	4	166	8	575	19	223	2	4,052	56
Plaza	971	72	407	17	440	63	1,420	9	142	17	444	24	20	5	3,844	207
Subtotal	2,762	106	1,019	28	1,239	101	3,725	20	512	51	1,356	73	258	8	10,871	387
Montana																
Ismay	1,979	10	312	1	0	0	0	0	15	1	33	0	113	2	2,452	14
Plentywood	1,176	46	771	4	235	26	442	4	9	4	42	4	21	6	2,696	94
Morgan	4,686	17	0	0	0	0	170	1	1	3	22	0	59	0	4,938	21
Subtotal	7,841	73	1,083	5	235	26	612	5	25	8	97	4	193	8	10,086	129
Total	13,387	260	3,218	54	1,741	145	5,385	30	678	64	2,167	99	862	26	27,438	678

[1] Four searches were conducted on the Sharon transect.

Table 2.--Number of nests found by species and habitats on air/ground transects in South Dakota, North Dakota, and Montana, 1983. Acres searched in ( ).

Species	Grassland (13,387)	Hayland (3,218)	Planted Cover (1,741)	Cropland (5,385)	Other (678)	Right-of-way (2,167)	Wetland (862)	Total (27,438)
Mallard	25	9	23	3	5	29	5	99
Gadwall	32	11	52	1	11	19	3	129
Wigeon	8	0	3	0	1	0	0	12
G-w Teal	2	0	0	0	1	0	0	3
B-w Teal	119	22	46	7	33	42	9	278
Shoveler	24	3	11	0	7	2	1	48
Pintail	38	9	8	19	4	7	1	86
Redhead	0	0	0	0	1	0	0	1
L. Scaup	12	0	2	0	1	0	4	19
Ruddy	0	0	0	0	0	0	3	3
Total	260	54	145	30	64	99	26	678

Five percent of the nests were destroyed by agricultural operations, while abandonment, weather and other factors caused the loss of only 2 percent of the nests.

Mayfield nest success estimates were calculated from 654 nests of the 678 nests found. Nests for which fates were not known contributed daily survival rate data to the Mayfield nest success calculations (Klett et al. 1986).

The number of successful nests and Mayfield nest success estimates for all nests are shown for each habitat and transect in table 4. Average nest success of all ducks was 11.5 percent in North Dakota, 11.4 percent in South Dakota and 17.5 percent in Montana. Average nest success rates were highly variable between transects ranging from 14 (Hosmer) to 42 (Ismay) percent. Average nest success estimates were highest in hayland (22 percent) and planted cover (19 percent) and lowest in cropland (3 percent). Nest success in grassland was 13 percent. Average nest success was highest in planted cover in North Dakota (19 percent) and in hayland in South Dakota (30 percent) and Montana (62 percent).

Nest success estimates by species and transect are presented in table 5. Mallards and pintails had the lowest nesting success (7 percent). Mallard nest success ranged from 3 percent on the Madison and Streeter transects to 26 percent on the Morgan transect. Pintail nest success ranged from zero (Hosmer) to 60 percent (Morgan). Blue-winged teal success averaged 13 percent ranging from 2 (Hosmer) to 100 percent (Ismay). Gadwall and wigeon had overall success rates of 22 and 25 percent, respectively. Mallard nest success averaged 4.7 percent in North Dakota, 5.4 percent in South Dakota and 18.9 percent in Montana.

Line transect surveys indicated that neither crows or magpies were common on the study transects. Although magpies were known to occur on some of the areas, none were tallied on any of the line transect

Table 3.--Fate of duck nests found on air/ground transects in South Dakota, North Dakota, and Montana, 1983. Percent of total shown in ( ).

State and Transect	Number Successful		Number Destroyed: Predator		Agriculture		Weather		Other		Number Abandoned		Total
South Dakota													
Hosmer	1		5		1		0		0		1		8
Madison	15		61		0		1		0		0		77
Parkston	19		33		5		0		1		1		59
Subtotal	35	(24)	99	(69)	6	(4)	1	(tr)	1	(tr)	2	(1)	144
North Dakota													
Streeter	19		81		11		4		0		1		116
Sharon	10		39		5		0		0		0		54
Plaza	57		130		4		0		0		1		192
Subtotal	86	(24)	250	(69)	20	(6)	4	(1)	0	(-)	2	(tr)	362
Montana													
Ismay	8		2		0		1		0		1		12
Plentywood	34		48		2		0		1		2		87
Morgan	11		8		1		0		0		0		20
Subtotal	53	(45)	58	(49)	3	(3)	1	(1)	1	(1)	3	(3)	119
Total	174	(28)	407	(65)	29	(5)	6	(tr)	2	(tr)	7	(1)	625

tr = <1%

Table 4.--Number of successful duck nests and Mayfield nest success[1] by habitat for air/ground transects in South Dakota, North Dakota, and Montana, 1983.

State and Transect	Grassland N	%	Hayland N	%	Planted Cover N	%	Cropland N	%	Other N	%	Right-of-way N	%	Wetland N	%	Total N	%
South Dakota																
Hosmer	0	<1	0	3	--	--	0	2	--	--	1	15	--	--	1	4
Madison	5	6	4	29	6	17	0	19	--	--	0	<1	0	<1	15	7
Parkston	11	22	4	39	--	--	0	<1	1	9	2	8	1	46	19	19
Subtotal	16	11	8	30	6	17	0	2	1	9	3	4	1	5	35	11
North Dakota																
Streeter	3	7	3	40	3	6	1	5	4	9	5	8	0	2	19	9
Sharon	1	30	1	28	4	11	0	6	3	21	1	1	0	1	10	8
Plaza	19	13	2	4	28	29	0	2	2	9	4	10	2	26	57	15
Subtotal	23	12	6	12	35	19	1	3	9	11	10	6	2	10	86	12
Montana																
Ismay	6	52	1	100	--	--	--	--	1	100	--	--	0	3	8	42
Plentywood	16	11	3	58	11	22	1	<1	1	3	0	3	2	26	34	14
Morgan	10	36	--	--	--	--	0	4	1	<1	--	--	--	--	11	24
Subtotal	32	19	4	62	11	22	1	1	3	4	0	3	2	16	52	17
Total	71	13	18	22	52	19	2	3	13	10	13	6	5	10	174	12

1 Average Mayfield nest success estimates for habitats and transects is weighted by exposure period and daily mortality rate.

surveys. Crows were detected on seven of the nine study areas but were not abundant anywhere (table 6). No crows were found on the Plaza or Ismay transects. Madison had the highest occurrence rate with crows being detected on an average of only 1.1 percent of the sample plots and on an average of 2.2 percent of the quarter section sample units.

Traps for Franklin's ground squirrels were set during a total of 1394 24-hour trap periods on seven transects. The number of trap-days on each transect were as follows: Hosmer-199, Madison-200, Parkston-200, Plaza-200, Sharon-200, Streeter-199 and Plentywood-196. A total of five Franklin's ground squirrels were captured; one on the Sharon transect and four on the Streeter transect. No animals were captured more than once.

Tracks of five carnivores were found on all transects surveyed except in two cases (table 7). Coyote tracks were not found on the Sharon transect in eastern North Dakota and raccoon tracks were not found on the Morgan transect in north-central Montana. Red fox tracks were found on more than 40 percent of the sample units on all transects except Morgan (17 percent). Red fox tracks were found most frequently on transects in North Dakota. Badger tracks were present on all transects and were more frequent on the Streeter

Table 5.--Number of ducks nests found (N), number of successful nests (S) and Mayfield nest success (%)[1] on air/ground transects in South Dakota, North Dakota, and Montana, 1983.

	South Dakota									North Dakota									Montana											
	Hosmer			Madison			Parkston			Streeter			Sharon			Plaza			Ismay			Plenty-Wood			Morgan			All Transects		
Species	N	S	%	N	S	%	N	S	%	N	S	%	N	S	%	N	S	%	N	S	%	N	S	%	N	S	%	N	S	%
Mallard	5	1	12	15	1	3	6	0	12	21	2	3	4	0	4	29	5	6	3	1	16	14	7	18	2	1	26	99	18	7
Gadwall	0	-	-	2	2	100	3	1	24	22	5	18	6	1	6	66	23	24	1	0	3	25	10	24	4	2	37	128	44	22
Wigeon	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-	4	1	14	4	2	100	2	1	10	2	1	30	12	5	26
G-W Teal	0	-	-	1	0	0	0	-	-	0	-	-	1	1	100	1	0	0	0	0	-	0	-	-	0	-	-	3	1	33
B-W Teal	1	0	2	53	12	10	53	15	22	59	10	10	42	8	8	52	15	15	4	4	100	14	5	14	0	-	-	278	69	13
Shoveler	0	-	-	2	0	0	1	0	4	9	0	2	2	0	0	22	6	17	0	-	-	10	3	10	2	0	2	48	9	8
Pintail	2	0	0	5	0	4	10	2	2	13	2	9	1	0	3	24	4	6	2	1	17	21	8	5	8	6	60	86	23	7
Redhead	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-	1	0	0	1	0	0
L. Scaup	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-	9	3	14	0	-	-	8	-	5	2	1	4	19	4	9
Ruddy	0	-	-	0	-	-	3	-	100	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-	3	1	100
Total	8	1	4	78	15	7	76	19	19	124	19	9	56	10	8	207	57	15	14	8	42	94	34	14	21	11	24	678	174	12

[1] Average Mayfield nest success estimates for transects and species is weighted by exposure period and daily mortality rate.

Table 6.--Average percentage of 1/8 mile radius half-circle sample plots and 160 acre sample units on which crows were detected during line transect counts along a 10 mi predator survey route on air/ground study transects in South Dakota, North Dakota and Montana, 1983.

State and Transect	No. Surveys Conducted	% Plots With Crows	% 160A Sample Units With Crows
South Dakota			
Hosmer	6	0.0	0.8
Madison	9	1.1	2.2
Parkston	9	0.8	1.7
North Dakota			
Streeter	9	0.3	0.3
Sharon	9	0.3	0.6
Plaza	9	0.0	0.0
Montana			
Ismay	7	0.0	0.0
Plentywood	9	1.1	1.1
Morgan	9	0.0	0.3

Table 7. Percentage of ¼-section sample units on each 10 mi transect where tracks of specified carnivores were found during a single search conducted during May or June in South Dakota, North Dakota and Montana, 1983

State and Transect	No. Sample Units Searched	Badger	Coyote	Raccoon	Red Fox	Strpd. Skunk
South Dakota						
Hosmer	40	17	7	35	42	44
Madison	40	22	2	67	45	5
Parkston	34	50	9	79	59	47
North Dakota						
Streeter	40	82	47	65	57	42
Sharon	40	17	0	40	88	70
Plaza	39	18	5	55	69	36
Montana						
Morgan	36	53	14	0	17	69
Plentywood	19	74	42	16	58	95
Ismay	-	-	-	-	-	-

(82 percent) and Plentywood (74 percent) transects. Coyote tracks were uncommon except on Streeter (47 percent) and Plentywood (42 percent). Raccoon tracks were common on all transects in the Dakotas (found on 35 to 79 percent of the sample units) but in Montana raccoons occurred only on the Plentywood (16 percent) transect. Striped skunk were also common, with tracks occurring on 36 to 95 percent of all sample units except for the Madison transect (5 percent).

Data on the occurrence of long-tailed weasels and additional data on Franklin's ground squirrels and magpies were obtained from observation of these species during 2993 investigator hours during 581 investigator days. The results are expressed as an observation rate (the average number of places per day per investigator hour where field personnel saw individuals of each species) (table 8). Franklin's ground squirrels were observed on the Parkston,

Table 8.--Average number of places per day per investigator hour (observation rate) where field personnel saw individual predator species on air/ground study transects in South Dakota, North Dakota and Montana, 1983.

State and Transect	Number Invest. Days	Number Invest. Hours	Franklin's Ground Squirrel	Magpie	Long-tailed Weasel
South Dakota					
Hosmer	83	431	0.000	0.036	0.005
Madison	93	471	0.000	0.000	0.006
Parkston	86	458	0.002	0.000	0.002
North Dakota					
Plaza	54	453	0.000	0.000	0.007
Sharon	63	514	0.012	0.000	0.002
Streeter	49	416	0.002	0.000	0.000
Montana					
Morgan	42	290	0.003[1]	0.000	0.000
Plentywood	58	435	0.002[1]	0.036	0.000
Ismay	53	387	0.000	0.000	0.000

[1] One sighting of a Franklin's ground squirrel was recorded, but the transect is outside the recognized geographic range of the species.

Sharon, Streeter, Morgan and Plentywood transects. The Morgan and Plentywood transects are outside of the recognized range for this species (Hall 1981). Magpies were recorded only on the Hosmer and Plentywood transects. Long-tailed weasels were recorded on all three South Dakota transects and on the Plaza and Sharon transects in North Dakota.

DISCUSSION

Results of this study support previous work showing that upland nesting ducks throughout much of the Prairie Pothole Region have extremely low nest success rates (Cowardin et al. 1985, Greenwood et al. in press, Klett et al. in press, and many others). Of particular significance are the nest estimates obtained for mallard, pintail, and blue-winged teal, three species which are experiencing serious population declines (North American Waterfowl Management Plan 1986).

Cowardin et al. (1985) presented information suggesting that mallards in central North Dakota require a nest success rate of at least 15 percent to maintain a stable population. Similarly, it has been proposed by Klett et al. (in press) that population stability requires nest success rates of 15 percent for pintails and 20 percent for blue-winged teal. Although nest success rates in this study varied by location and habitat, they were generally below these threshold levels (table 5). Results from the study of stabilized hunting regulations show similar results for the Prairie Pothole Region of Canada (Figure 1) (Greenwood 1987)[7].

[7] op. cit.

This study also clearly shows that predation is the most important cause of duck nest failure in the areas studied. Losses to predators were equally high in all three states with predators destroying 88 to 91 percent of all unsuccessful nests. Losses due to agricultural practices, weather and abandonment were insignificant, compared to predation, despite the fact that virtually all nests were found on lands not managed for wildlife production.

While we obtained considerable data on the occurrence of predators between study areas, we were unable to relate differences in nest success rates to differences in predator abundance. This may have been due to several factors including, but not limited to: 1) high predation rates on nearly all transects, regardless of predator populations; 2) effects of compensatory predation (Balser et al. 1968) by different species in different areas; 3) sensitivity of the surveys in detecting differences in predator abundance; and 4) differences in habitat quantity and quality and the abundance of buffer prey species between areas.

Because crows, magpies, long-tailed weasels and Franklin's ground squirrels were scarce to absent in all areas, it seems reasonable that nest predation in this study can be attributed to red fox, skunk, raccoon, badger and coyote. Although, other predators, not surveyed, may have destroyed some nests, most of these five carnivores existed, and were generally abundant on all transects (no data for Ismay). Of these, red fox is considered to be the most serious predator of duck nests. The impacts of red fox predation or prairie nesting ducks has been discussed extensively by Sargeant (1972), Johnson and Sargeant (1977), and Sargeant et al. (1984). Red fox are not only capable of destroying a high percentage of the nests within their territory but they also have a propensity to take nesting hens. Johnson and Sargeant (1977) estimated that red fox take 18 percent of the hen mallards which nest in North Dakota each year and Sargeant et al. (1984) estimated that an average of 900,000 adult ducks (predominantly hens) are killed by red fox in the mid-continent area annually.

The impacts of badgers, skunks and raccoons on nesting ducks is not as well documented, however several studies have demonstrated increased nest success by reducing the number of these predators (Balser, Dill and Nelson 1968, Duebbert and Kantrud 1974, Duebbert and Lokemoen 1980, and Greenwood 1986). Coyotes are generally not a serious nest predator because they occur in low densities and are often beneficial because they tend to exclude red fox from their large territories (Johnson and Sargeant 1977).

While the problem seems clear, the solutions are not. Although predation is the immediate factor responsible for low nest success, the ultimate cause is habitat destruction. The extensive and continuing loss of wetland pair habitat and upland nesting habitat due to intensified agriculture has forced nesting ducks into progressively smaller islands of habitat.

These same islands of cover are also prime areas of predator use (Cowardin, Sargeant and Duebbert 1983) Potentials for dealing with high predation rates on public lands managed for waterfowl production have been discussed by Sargeant and Arnold (1984). However, a relatively small percentage of the total waterfowl population in the Prairie Pothole Region currently nests on these managed areas. While it is important to make dedicated wildlife areas produce to their fullest potential (Duebbert and Lokemoen 1980), it can also be a very costly proposition to do so (Lokemoen 1984). It seems reasònable to direct additional work at improving duck nest success on the private lands where a large percentage of ducks nest (Hochbaum and Bossenmaier 1965 and Cowardin and Johnson 1983[8]) and to continue to work diligently at maintaining waterfowl habitat on both public and private lands.

Some waterfowl biologists argue that once a series of good water years returns to the prairies, ducks will flourish. Unfortunately, good water conditions will attract ducks to many areas of the Prairie Pothole Region where they cannot successfully reproduce because of lack of secure nesting cover and high predation rates (Cowardin et al. 1985). Others believe that restrictive hunting regulations will improve the status of ducks. While harvest strategies which increase the survival of hens can be beneficial, regulations which simply reduce hunting opportunity and the harvest of drakes do not effectively address the problem facing prairie nesting ducks. In our opinion, the continuing trend of decreasing habitat and the increasing impacts of predators will override any potential long term benefits which can be derived from improved water conditions and reduced hunting mortality.

We agree with Sargeant et al. (1984) that in the immediate future, managers seem to have two broad choices, either coping with or reducing high levels of predation. Predator reduction can take several forms: direct control such as trapping, poisoning (currently not permitted) and shooting or indirect control such as more liberal hunting and trapping seasons, altering predator habitats and encouraging alternative competitive species (e.g. coyotes vs. red fox). Regulations which currently protect red fox and encourage the taking of coyotes in North Dakota and South Dakota are detrimental to prairie nesting ducks. These options all have considerable biological, social, economic and moral implications.

Coping with high predation rates entails relatively expensive management options such as electric fences, islands and nest structures (Lokemoen 1984). If the current decline in duck numbers is to be resolved, managers in each area of the prairie pothole region will need to carefully evaluate their local situations and employ management activities which are most efficient in improving production. For example, in areas with low predation rates, production can be improved simply by attracting additional breeding pairs and providing attractive nesting cover. In areas with high predation rates, managers will need to improve nest success by intensive control of predators or by separating nesting ducks from predators using a variety of techniques.

The NPWRC mallard recuritment model will be a valuable tool in making these management decisions. The data collected in this study is now incorporated into the model and has improved its accuracy in predicting the impacts of various management options. The Central Flyway Council has used the model for this purpose (Cowardin et al. 1984[9]) and has incorporated the results into a Central Flyway Mallard Management Plan which provides a set of guidelines designed to maintain a huntable supply of mallards. Other agencies will need to undertake a similar approach if they are to make informed decisions regarding management and preservation of prairie nesting ducks.

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Predator Management To Increase Duck Nest Success[1]

Harold A. Doty[2] and Anthony J. Rondeau[3]

Abstract.--Operational programs of seasonal predator management to increase duck production may be economically feasible. Mammalian predators of nesting ducks and their eggs were reduced in numbers on selected areas of west central Minnesota during the nesting seasons 1982-86. Where predators were removed, nest success averaged 30% while nest success on nearby untreated habitat was 10%.

INTRODUCTION

Nesting failures by wild ducks in the mid-continental prairie wetland region are mainly the result of mammalian predation on eggs and nesting females. The separation of predators from duck nest habitats via natural barriers has resulted in higher reproduction by upland nesting ducks (Duebbert et al. 1983). The simulation of reduced predation conditions to increase waterfowl production on areas of treatment have been attempted over time in several locations through various mechanical procedures and techniques.

The Mid-Continent Waterfowl Management Project (MCWMP) of the U.S. Fish and Wildlife Service (FWS) initiated a pilot predator management operation in 1982 in three western Minnesota counties in an effort to increase duck nest success without cover management changes. In this project we tried to increase duck nest success on trial areas or zones through prescribed methods of predator removal during a series of nesting seasons.

Wildlife managers and administrators are often confronted with questions of cost-benefit ratios. We have addressed this aspect of a seasonal predator management program. The operational expenditures of this trial effort were documented and were linked to data from previously reported investigations along with our findings. This resulted in our estimated cost of new ducks (recruits) that we believe were produced. The projections are necessarily subject to change as additional data are compiled and examined. In the interim, they offer a point of reference.

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INFORMATION REVIEW

The manipulation of upland vegetation has not provided consistent protection of duck nests from terrestrial predators. Cowardin and Johnson (1979) concluded that predator reductions (in waterfowl nesting habitats) combined with cover management are more effective for increasing recruitment than cover management alone. Idle seeded grasslands on most FWS Waterfowl Production Areas (WPAs) provide nest cover that is attractive to ducks. They also provide habitat conditions which favor relatively high populations of Franklin's ground squirrels (Spermophilus franklinii) locally. This species was identified as a nest predator by Sowls (1948) but has not often been recognized as an especially important threat to duck nests. More recently it was found that inside electric barrier fences designed primarily to exclude larger mammalian predators, the depredation of duck nests by Franklin's ground squirrels could rise to damaging levels (Lokemoen et al. 1982). During a study of Franklin's ground squirrels in North Dakota, Choromanski and Sargeant (1982) found that about 50 adults inhabited 286 acres of dense nest cover on a WPA. They concluded that substantial losses of duck production could be inflicted as the ground squirrels made extensive movements through the dense cover.

In eastern North Dakota and western Minnesota the list of mammalian predators of ducks and their eggs is long. In addition to Franklin's ground squirrels the list includes badgers (Taxidea taxus) (Duebbert 1969), mink (Mustela vison) (Eberhardt 1973 and Sargeant et al. 1973)

raccoons (Procyon lotor) (Greenwood 1982), striped skunks (Mephitis mephitis) (Greenwood 1986), and red fox (Vulpes vulpes) (Johnson, D. H. and A. B. Sargeant 1977). The latter investigators determined that 18% of female mallards (Anas platyrhychos) are killed annually in North Dakota by red foxes, generally while the ducks are attending nests on upland sites. When Sargeant et al. (1984) conducted an extensive study of red fox predation on breeding ducks they found that the average fox family used 3.8 rearing dens during the denning season. Among 1,432 rearing dens they examined, the single den with the remains of the most individual ducks (n=67) was discovered in June, 1970 on the J. Clark Salyer National Wildlife Refuge (NWR), North Dakota. That refuge was formerly named the Lower Souris Refuge where E. R. Kalmbach identified red fox as a predator of ducks. In a very prophetic observation Kalmbach (1938) noted that red fox appeared in 1937 as a predator on the refuge and warned that it would become a factor of concern if its numbers increased.

Concern for the security of duck nests from depredation led to the initiation of a field study in 1934 (Kalmbach 1937) by the U.S. Biological Survey, predecessor of the FWS. He reported that egg destruction by crows (Corvus brachyrhynchos) occurred in 31% of duck nests found during 1934-35 in Saskatchewan and Alberta, respectively. In 1936 Kalmbach (1938) found that 30% of duck nests on Lower Souris Refuge were destroyed by skunks but less than 2% were damaged by crows, which were not numerous in that relatively treeless area. The overall rate of observed duck nest success was 54%. He also noted that in the winter of 1936-37, 423 skunks were trapped and removed to determine if that action would influence duck production. During the 1937 nesting season where the skunk removal had taken place only 7% of discovered duck nests (n=566) were destroyed by skunks and the observed nest success increased to 69%.

Another effort to influence duck nest success, more than 20 years after the Lower Souris Refuge study, was conducted during 1959-64 on the Agassiz NWR in northwest Minnesota (Balser et al. 1968). At Agassiz NWR duck nest success doubled and duckling production increased 60% on the predator reduction treatment areas. To reach the desired level of predator reduction, strychnine eggs, livetraps, steel traps, and Conibear traps were used.

The Minnesota Department of Natural Resources investigated the effect of predator removal on ring-necked pheasants (Phasianus colchicus) reproductive success on an area in southern Minnesota during 1960-62 (Chesness et al. 1968). Predators were removed from the area with livetraps, steel traps, shooting, and by den treatment with poison-gas cartridges. They found that intensified predator removal increased nest success on the trapped area during each successive year while nest success on the untrapped area remained low. That study demonstrated that predation was an important factor limiting pheasant nest success and production. They recommended that predator removal continue throughout the pheasant nesting season where predators were numerous.

In 1967-71 the South Dakota Department of Game, Fish and Parks conducted a program of predator reduction (Trautman et al. 1973). During that program, Duebbert and Kantrud (1974) observed duck nesting near Hosmer, South Dakota, and found that duckling production was over four times greater in the area where predators were removed than where they were not (22.0 vs. 4.8 ducklings/hectare). Eighty-five percent of the predator removal effectiveness was attributed to poisoning, 10% to trapping, and 5% to shooting. Mallard pairs on the area near Hosmer increased sixfold from 7 to 43 pairs/mi^2 during 1970-72 when predator reduction was most effective (Duebbert and Lokemoen 1980).

Sargeant et al. (1984) reported that an effective program to reduce predation on nesting waterfowl would have to include reduction of red fox populations. Regarding the relatively high numbers of red fox in the eastern prairie wetland region, they felt that the demise of coyote (Canis latrans) populations had permitted expansion of red fox populations. Current knowledge of the impact that coyotes have on nesting ducks is limited, but recent evidence indicates that coyotes have less impact on upland nesting ducks than red foxes (A. B. Sargeant and S. H. Allen, unpubl. data).

Red fox densities may be suppressed, eliminated, or excluded in much of the western United States where coyotes dominate. In some locations where coyotes are especially abundant they, too, can cause a substantial reduction in duck nest success. A predator reduction program was directed at coyotes (taken mainly by aerial gunning), raccoons, and ravens (Corvus corax) on a segment of the Malheur NWR, Oregon in 1986 (David G. Paullin, personal communication, 1-15-87). The purpose of that activity was to enhance the production of greater sandhill cranes (Grus canadensis) by reducing predation losses but it also increased duck nest success. Apparent nest success on the predator reduction area was 82% for dabbling ducks and 100% for diving ducks while the comparative rates from areas of the refuge without predator reduction were 25% and 67%, respectively.

Another program pertaining to predator removal took place in Alaska during the spring of 1986. A nesting colony of Pacific black brant (Branta nigricans) near the Tutakoke River suffered disasterous nest losses in 1984 and 1985 when nest success was about 3% and 6%,

respectively. With the removal of Arctic fox (Alopex lagopus) during the spring and summer of 1986, brant nest success rose to 83% (Anthony and Sedinger 1987).

Implications

The preceding review along with a host of unpublished data could provide waterfowl production managers with sufficient evidence to proceed with organized programs of predator management. Extremely large numbers of wild ducks can, under proper man-made or natural conditions, be supported on relatively small units of habitat with intensive management. In the absence of nest destruction by predators, small tracts of attractive nest cover can yield several thousand ducklings per acre (Duebbert et al. 1983). While it may be unrealistic to strive for that level of success on intensively managed habitats, it does illustrate that the upper limits of duck production are sufficiently high to justify relatively large expenditures.

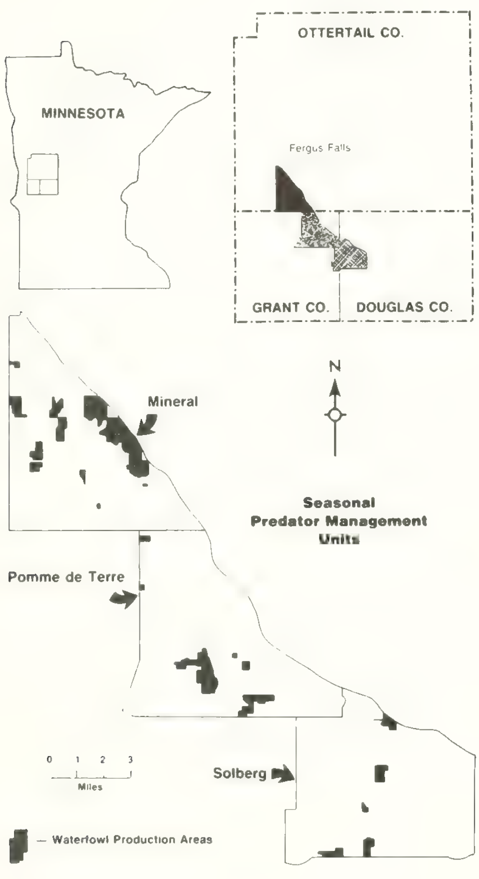

Figure 1.--Field activity areas.

THE AREA AND PROCEDURES USED

Seasonal predator management was conducted annually in April through June, 1982-86. Predator removal by trapping took place on three similar sized units of land, identified as Mineral, Pomme de Terre, and Solberg (fig. 1). These areas were in Otter Tail, Grant, and Douglas counties, Minnesota. They are on the eastern fringe of the prairie pothole region (Stewart and Kantrud 1973) and just east of the Agassiz Lake plain.

Trapping was done in close proximity to roads which bound nearly all sections of land. Major private land (about 90% of the area) usage was for cash crops, mainly corn, soybeans, oats, barley, wheat, and buckwheat. The presence of pasture and hayland was uncommon. WPAs constituted about 6% of the 142-square-mile area in the predator management units. Within the three units, there were about 121-square-miles of uplands which could be used by terrestrial predators and concurrently provide nest sites for dabbling ducks. About 3.6% of the uplands were situated on WPAs where the predominant condition was idle grassland.

In 1982 and 1983 livetraps were used exclusively to remove striped skunks and Franklin's ground squirrels. In the initial year, trapping took place only on the public and private lands in the Mineral unit. Predator reduction on privately-owned lands was conducted with the permission of landowners and was restricted to removals of striped skunks and Franklin's ground squirrels throughout the 1982-86 period. In 1983 the Pomme de Terre unit was added. In 1984 the Solberg unit was included along with procedures for the removal of additional species of predators. On all WPAs mechanical traps and wire snares were used to take red fox and raccoons; incidental captures of badgers and mink also occurred. On one WPA, strychnine-treated milo seed was used in ground squirrel burrows. Numbers of animals taken were recorded except for undiscovered Franklin's ground squirrels which consumed treated milo in their burrows. During 1985 and 1986 the program was continued as in 1984 except that treated milo and snares were not used. Shooting was rarely used to take predators and that action was confined to WPA lands. Dispatched animals were either shot or injected with a euthanasic drug and were disposed of daily in sanitary landfills. Road-killed predators were also noted and included in the records of known removals.

Table 1.--Areas of treatment and numbers of predators removed.

Year	Square miles: Area treated	Upland[1]	Other[2]	Individuals(n) removed: Striped skunk	Franklin ground squirrel	Red fox[3] adult	Raccoon
1982	47	36	11	79	27	0	0
1983	92	76	16	157	69	0	0
1984	142	121	21	270	53	22	61
1985	142	121	21	263	60	15	40
1986	142	121	21	266	118	27	53
Total	565	475	90	1035	327	64	154

[1] Estimated to be springtime habitat for skunks, fox, and raccoons.
[2] Includes areas of deep marsh, lake, river, roads, and residential.
[3] 37 pups were transported and released alive on public lands at a distance and additionally 28 pups were dispatched near dens.
Note - 5 mink and 15 badgers removed during the period.

Seasonal predator management was conducted in a manner that would approximate an operational program. Young persons with wildlife profession backgrounds were hired for 3-month periods annually and learned trapping techniques and routines through on-the-job training. Field operations required the equivalent of 3-person months in 1982, 6 in 1983, and 12 per season during 1984-86.

Annually (1979-82) during early May, surveys were conducted to record indicated pairs of breeding ducks in the tri-county area (fig. 1). Blue-winged teal (*Anas discors*), mallards, gadwalls (*A. strepera*), Northern pintails, (*A. acuta*), Northern shovelers (*A. clypeata*), and green-winged teal (*A. crecca*) were found to be the most common species of upland nesting dabbling ducks on the areas where predator management was conducted. Systematic nest searching with motor vehicles and chain drags (Klett et al. 1986) was done each year, 1979-86, mainly in the idle grassland fields on WPAs. Nest success was calculated via the Mayfield method (Miller and Johnson 1978).

Predator Population Reduction

About 80% of all striped skunk captures occurred by mid-May each year. The overall average annual take was slightly above 2 animals/mi^2 of habitable uplands (table 1). That density of striped skunks was very comparable to the population reported by Greenwood et al. (1985) on a study area in southeast North Dakota. The capture and removal of Franklin's ground squirrels, raccoons, and especially red fox was very likely much less effective or complete than appeared to be the case with striped skunks. A trap density of about 2 livetraps/mi^2 may have been insufficient to significantly reduce Franklin's ground squirrel numbers. The procedure of containing our trapping of raccoons and red fox on WPA uplands probably reduced our effectiveness in reducing their numbers throughout the treated units. Raccoons were taken as easily with livetraps as with steel traps. The number captured and released unharmed on private lands (n=255) during 1982-86 exceeded the number (n=154) taken on WPAs (table 1). Red fox adults were not known to enter livetraps and the tracks of surviving animals were present at all times on each of the three units.

The predator removal procedures used during this seasonal predator management trial were labor intensive and 78% of the \$229/mi^2 annual expenditures were attributed to labor (table 2). Methods to reduce the cost of operation during the 1984-86 period would only have been possible by reducing labor costs or by holding those costs constant while increasing the area of treatment. The cost of striped skunk and Franklin's ground squirrel removal only during 1982-83 was only a few dollars less/mi^2 than the total cost of the expanded seasonal predator management routine used in the 1984-86 period.

Table 2.--Operational trial expenses, 1984-86.

Item	Average annual costs/mi^2
Labor and administration	\$178
Vehicles, fuel, and upkeep	30
Durable equipment	5
Expendable supplies	16
Total	\$229

Duck Nest Success

The composition by species of discovered nests was 74% blue-winged teal, 17% mallards, 4% gadwalls, 3% Northern shovelers, 2% Northern pintails, and a trace of green-winged teal. This was similar to the species composition as determined during the surveys of indicated breeding pairs. On non-treated WPA grassland our measure of nest success for 361 nests was 10% with minor variations during 1980-86 (table 3). For mallards this would represent about 22% hen success when estimates of renesting are considered (Cowardin and Johnson 1979). With the reduction of skunks and ground squirrels in 1982-83 our records of duck nests (n=57) indicated 21% nest success. When predator management procedures were intensified during 1984-86, nest success was 33% among 487 nests.

We took liberty with some parts of our data and borrowed from others in estimating duck production. We made some assumptions: (1) the dabbling duck population on treated and non-treated areas in the prairie habitat zone was 40 pairs/mi^2 as found during our breeding pair surveys, (2) our observation of 8.8 eggs hatched per successful nest was representative, (3) the 54% duck survival rate used by Lokemoen (1984) was applicable to this area, and (4) mallard hen success as described by Cowardin and Johnson (1979) was used in our treatment of mixed dabbler nest data (table 4). By this process we would predict an increase in new recruits (increase in fledged ducks) through seasonal predator management. Some increases in nest success (table 3) and estimated production (table 4) were noted during the 1982-83 period but substantial additional increases were recorded in the 1984-86 period. In this latter period red fox, raccoons, badgers, and mink were added to the list of predators to remove from WPAs and that change probably accounted for the increased nest success. Our highest estimated annual number of ducks fledged/mi^2 (n=95) (table 4) was 52 more than our estimate for the 1980-86 period (n=43) where no predator management was used. With an annual/mi^2 expenditure of $229 (table 2), the cost-benefit ratio for this specific form of predator management could be expressed as $4.40 for each new recruit. This does not, of course, include the costs of land acquisition and management.

Table 3.--Duck nest success with and without seasonal predator removal in WPA grassland nest cover, 1980-86.

Treatment	Nests (n)	Nest exposure days	Daily survival rate	Percent nest success mean	Percent nest success 95% CL
No predator removal 1980-86	361	3810	0.9320	10	7-13
Action #1[1]	57	664	0.9533	21	12-36
Action #2[2]	487	6652	0.9669	33	28-38

[1]Striped skunk and Franklin's ground squirrel removal on public and private land in 1982-83.

[2]Same as previous action plus added removal on FWS lands of red fox, raccoons, and incidental badgers and mink.

Table 4.--Estimates of production from dabbling duck nesting data.

Treatment[1]	Rate of hen success	Production estimates per mi^2/year: Clutches of eggs hatched	Production estimates per mi^2/year: Fledged ducks
No predator removal 1980-86	.22	9	43
Action #1	.39	16	76
Action #2	.50	20	95

[1]Treatments were the same as described in table 3.

CONCLUSION

Our goal to increase the rate of duck nest success by reducing nest losses to predators was achieved in spite of some procedural shortcomings. It can be surmised that several other species of wildlife were concurrently benefitted during their reproductive periods. Added benefits to other game and nongame wildlife reproduction, and consequential sport hunting or nonconsumptive uses can often be equated to economic benefits for resource agencies and user groups. The effectiveness of future programs to reduce mammalian predators of upland nests and birds during springtime might become more efficient over time. Additional procedures and experience gained could also increase outputs while limiting program costs.

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Duck Nest Success on South Dakota Game Production Areas[1]

S. Gay Simpson[2]

Abstract - Duck nesting success was studied on South Dakota Game Production Areas in 1985 and 1986. Mayfield success rates for all species combined were 28.0 and 28.4 percent, respectively. Predators were responsible for nearly 90 percent of nest failures. Results from lake Albert Island and Hogsback served to demonstrate potential for intensive management to increase duck nesting success.

INTRODUCTION

Increasing recruitment rates of upland nesting ducks, especially of mallards (Anas platyrhynchos), is a top priority in the Central Flyway. Funds have recently become available from private organizations such as Ducks Unlimited to attain this goal through habitat enhancement and intensive management. To estimate current nest densities and success and thus assess management potential on Game Production Areas (GPAs), the South Dakota Department of Game, Fish and Parks (SDGFP) initiated duck nesting studies in spring, 1985, and continued the work in 1986.

With the recent increased interest in improving nest success and recruitment of prairie nesting ducks, interest in high production potential of islands and other areas inaccessible to predators also increased. High densities of nesting ducks on islands were reported by Duebbert 1966, Newton and Campbell 1975, Duebbert et al. 1983, Browne et al. 1983, and Lokemoen et al, 1984. Drewein and Fredrickson (1970) reported high densities of nesting mallards on a 7.7 ha island in Lake Albert in Kingsbury County, South Dakota (Fig. 1). The island is owned by SDGFP, as is a 21 ha peninsula known as the Hogsback, which extends into the lake from the west shore. Nest searches were conducted on the island and Hogsback to determine nest density and success, to determine whether any changes in nest density had occurred on the island since 1967, and to evaluate suitability of the Hogsback for intensive management.

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STUDY AREAS

Searches were conducted on 19 and 24 GPAs in 13 counties of east-central and north-eastern South Dakota in 1985 and 1986, respectively (fig. 1). Areas were selected by: ease of dragging, management potential and preference of local Conservation Officers.

Lake Albert is a 1764 ha, deep open lake located in northeast Kingsbury and southeast Hamlin counties of South Dakota (fig. 1). Lake Albert Island, located in the southern portion of the lake, is partially wooded but contains an open flat of 3.6 ha dominated by stinging nettle (Urtica procera) and containing patches of western snowberry (Symphoricarpos occidentalis), woods rose (Rosa woodsii) and gooseberry (Ribes sp.). The Hogsback has steep wooded banks and an upland with interspersion of grasses and the same shrubs as occur on the island.

METHODS

Game Production Areas were searched by dragging 48 m of 1.9 mm chain between four-wheel drive vehicles and/or all-terrain vehicles. Search procedures were those described by Higgins et al. (1977). Areas not suitable for vehicular travel were searched on foot. First searches were conducted from 16 May through 16 July. Selected areas were searched a second time between 23 June and 24 July. Area of fields searched was measured using a polar planimeter and aerial photographs

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[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop, Rapid City, South Dakota, April 28-30, 1987.

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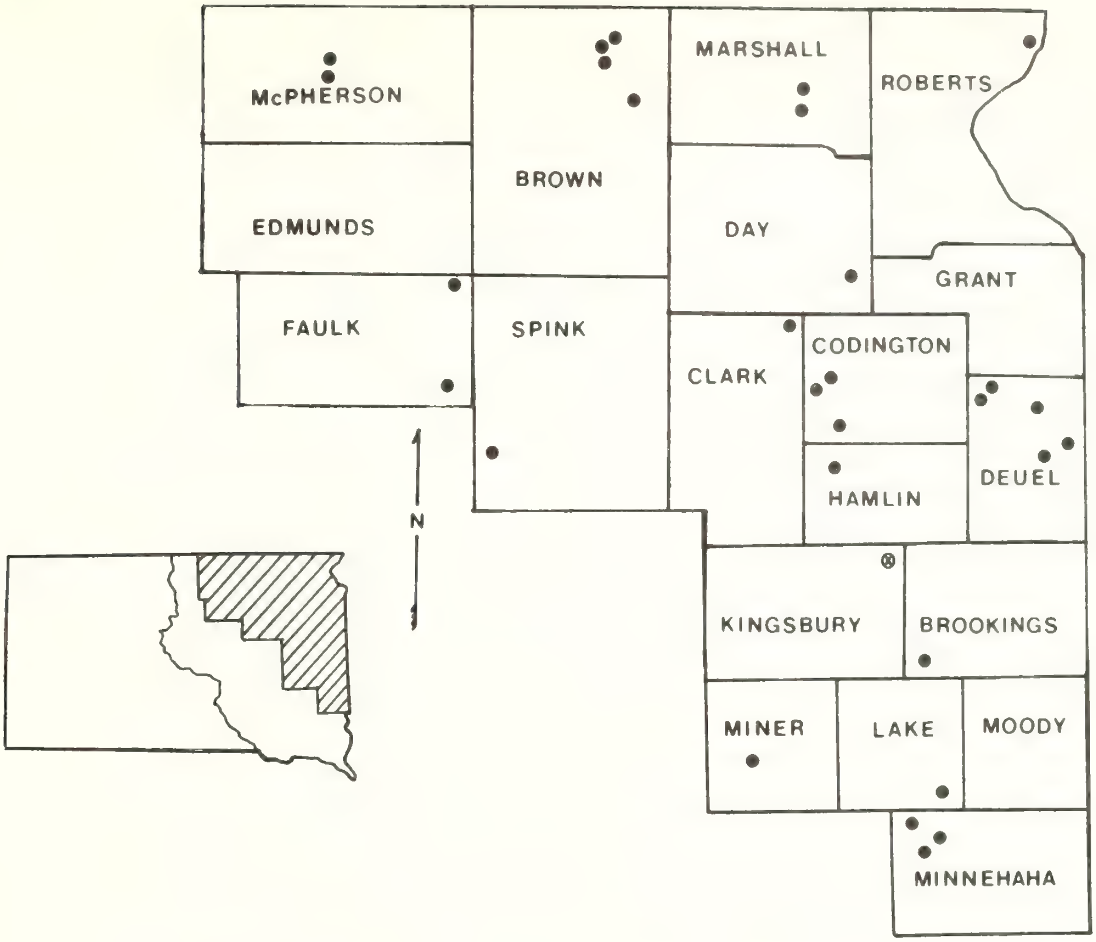

Figure 1. Locations of South Dakota Game Production Areas (●) where duck nesting studies were conducted in 1985 and 1986, and Lake Albert Island (⊗).

(provided by the Agricultural Stabilization and Conservation Service in each county).

Data recorded at each nest included species, clutch size, age of clutch (in days), dominant plant species, vegetation height/density, and (in 1986) whether the nest was in or between vehicle wheel tracks. Vegetation height/density was measured using a Robel pole (Robel et al. 1970) as suggested by Kirsch et al. (1978). We assumed a laying rate of one egg per day and candled eggs to estimate stage of incubation (Weller 1956). All data were recorded on standardized cards provided by Northern Prairie Wildlife Research Center (NPWRC), Jamestown, North Dakota.

Nests were revisited at least once to determine fate. A nest was considered successful if at least one egg hatched. Nests with no sign of eggs, shells or membranes or with scattered and eaten shells present were classified as destroyed (predated). Nests containing whole eggs which had ceased developing were recorded as abandoned.

Mayfield nest success (Mayfield 1961, 1975) and 95 percent confidence intervals were provided by NPWRC. Expanded nest densities accounting for all nests initiated and destroyed between searches (Miller and Johnson 1978) were calculated as in Klett et al. (1986). The G-test of independence was used to compare species composition of nests between years, and the chi-square test was used to compare fates of nests on and off wheel tracks (Sokal and Rohlf 1969).

In 1985, on Lake Albert Island, searchers walked less than 2 m apart and proceeded slowly on transects across the island. The east half of the flat was searched on May 14, the west half on May 19. Searches were conducted between 0700 h and 1400 h. Nests were marked with red survey flags or with orange flagging, wired or tied to residual vegetation at least 1 m tall, not more than 2 m from the nest. Clutch sizes were recorded but eggs were not candled. In 1986, the island was searched on June 30, after hatching had occurred.

The Hogsback was searched on 28 May, 1985, with 48 m of 1.9 mm chain drawn between vehicles. Nests were marked with flagging as on the island. Clutch sizes were recorded and eggs were candled to determine stage of incubation (Weller 1956). Nest locations were recorded on an aerial photograph obtained from the Agricultural Stabilization and Conservation Service. Fate of nests was recorded as on Game Production Areas. Mayfield nests success was calculated based on an average age of nests when found of 10 days, using the method of Johnson and Klett (1985). The Hogsback was not searched in 1986.

RESULTS

Game Production Areas

We located 200 nests on 302 ha in 1985, and 206 nests on 786 ha searched in 1986. Of the nests located each year, approximately 35 percent were found in laying stages, 55 to 65 percent in incubation, and the remainder pipping or hatched.

Species composition (table 1) was significantly different between years (G = 25.51, 6 d.f., $p \leq 0.01$). The difference was due to an increase in the proportion of the sample comprised of mallards (21.2 percent in 1986 compared to 7.7 percent in 1985) and a decrease in northern shovelers (_A. clypeata_) from 8.5 to 1.9 percent. Blue-winged teal (_A. discors_) comprised the majority of nests located both years and northern pintail (_A. acuta_), American wigeon (_A. americana_), and lesser scaup (_Aythya affinia_) remained unchanged at less than 3 percent of the sample each.

Expanded nest density in 1986 was 0.43 nests per ha, compared to 1.21 nests per ha in 1985. Only "normal" nests were used when calculating nest success. The remaining nests were not used because they were: not relocated, totally or partially destroyed in the search, or found predated during searches. Mayfield nest success was 28.4 percent for all species combined in 1986 (table 1), just very slightly higher than in 1985. Although Mayfield nest success rates for mallard (0.317), gadwall (0.380) and shoveler (0.574) in 1986 were more than double the 1985 rates (table 1), the increase was statistically significant only for gadwalls (X^2 = 8.50,1 d.f., $p < 0.01$). Increased sample size of mallards in 1986 probably enhanced Mayfield estimates for that species. Sample sizes for pintails, wigeon, shoveler and scaup were too small both years to provide accurate estimates of nest success, as indicated by 95 percent confidence limits ranging from 0 to 3355 percent (table 1).

Predation was responsible for 87 percent and 88 percent of nest failures in 1985 and 1986, respectively. Attempts were made to identify species of predators responsible for destruction of nests, based on visual evidence, predator sightings and sign, and information from local Conservation Officers. In 1986, skunks were implicated by evidence present at nine destroyed nests, and a ground squirrel at one. Active fox dens were present on nearly all GPAs searched (Conservation Officers, personal communications), and red fox were observed on two of the GPAs during nest searches. One badger (_Taxidea taxus_) burrow and four northern barrier (_Circus cyaneus_) nests were located on nest searches, and skunk and raccoon tracks were common. Evidence of hen mortality was found at one nest in 1985, and at three nests in 1986.

Nest success on GPAs was not independent of position of the nest with respect to vehicle tracks (n=195, X^2 = 31.8, 1 d.f. $p < 0.01$). Proportionately more nests in or between wheel

Table 1. Species Composition and Mayfield Success Rates of Duck Nests on Game Production Areas in Northeastern South Dakota in 1985 and 1986.

	1985			1986		
Species	N (%)	Mayfield Success	95% Confidence Limits	N (%)	Mayfield Success	95% Confidence Limits
		----%----			----%----	
Mallard	14(7.7)	15.4	(3.5-61.6)	39(21.2)	31.7	(18.1-56.1)
Gadwall	28(15.5)	16.2	(6.6-38.7)	29(15.8)	38.0	(21.6-66.1)
Wigeon	1(0.5)	1.7	(0.0-2581.3)	1(0.5)	2.4	(0.0-2057.4)
B.W. Teal	117(64.6)	37.5	(27.7-50.7)	105(57.1)	25.8	(17.6-37.8)
N. Shoveler	15(8.3)	21.8	(6.1-74.0)	4(2.2)	57.4	(18.6-171.1)
N. Pintail	5(2.8)	1.0	(0.0-75.0)	5(2.7)	6.0	(0.2-133.6)
L. Scaup	1(0.5)	2.4	(0.0-2057.4)	1(0.5)	1.1	(0.0-3355.2)
All	181	28.0		184	28.4	

tracks were destroyed by predators, suggesting predators use the vehicle tracks as travel lanes.

Lake Albert Island

In 1985 one great-horned owl was seen on Lake Albert Island when nest searching began. We located 63 mallard nests (table 2). Only three were found in the wooded portion of the island, which was not systematically searched; the remainder were found in the 3.6 ha field of nettle. Nest density in the field was 17.5 nests per ha.

We relocated only 44 (70 percent) of the 63 mallard nests on 21 June, and found three nests not located on earlier searches (table 2). Mayfield nest success was 43.2 percent. Fifteen nests (31.9 percent) were abandoned. In four abandoned nests where original clutches numbered 4, 6, 8 and 11, we found 11, 6, 13 and 10 eggs, respectively, at abandonment. Six nests (12.8 percent) were destroyed by predators. Remains of one hen were found near her nest.

We found eight nests on the Hogsback: five blue-winged teal, two gadwall and one mallard. Only three nests were relocated (mallard and gadwall), and all three were destroyed by predators. Cattle destroyed markers of all the teal nests.

In 1986, we located 38 nests on the island (table 2). Of those, 13 were successful (34.2 percent), eight were abandoned (21.1 percent) and 17 were destroyed (44.7 percent). Remains of hens were found at two nests and egg remains ascribed to raccoon activity were found at one nest. In addition, about 30 uneaten eggs were found scattered in the vegetation in an area approximately 8 m in diameter.

Table 2. Numbers and Fates of Mallard Nests on Lake Albert Island in Kingsbury County, South Dakota, in 1985 and 1986.

	1985	1986
Nests Found	63	38
Nests Relocated	47	[1]
Successful (%)	26 (55.3)	13 (34.1)
Abandoned (%)	15 (31.9)	8 (21.1)
Destroyed (%)	6 (12.8)	17 (44.7)
Mayfield Success	43.2%	[1]

[1]Only one search was conducted in 1986. No Mayfield nest success estimate was calculated.

DISCUSSION

Game Production Areas

Habitat conditions varied across the study area and between years. In 1986, both May pond counts and duck breeding populations in South Dakota increased significantly over 1985 levels (Novara 1986). Observed changes between years in nest densities and species composition on GPAs could be attributed in part to these changes in habitat conditions.

Species composition may have been biased by timing of nest searches, which began in mid-May. Klett et al. (1986) indicated that if only a single search were possible, late May would be optimal for mallard, blue-winged teal and all species combined. Of 69 fields searched only once, only seven were searched in late May. Of 20 fields search twice, 14 were searched in late May and again in mid-to-late June.

Estimates of Mayfield nest success on GPAs agreed closely with estimates from similar studies conducted by the U.S. Fish and Wildlife Service (USFWS) on Waterfowl Production Areas (WPAs) in the same region in 1984 and 1985.[3,4] That is, nest success on public lands "managed" for wildlife was approximately 30 percent for all species combined.

The primary cause of nest failure on GPAs was predation. The impact of mammalian predators on upland nesting ducks is well documented (Cowardin et al. 1983, Greenwood 1986, Higgins 1977, Johnson and Sargeant 1977, and others). Identification of predators responsible for destruction of nests from nest site inspection is difficult at best, and far from an exact science (Greenwood, personal communications). I used all available evidence, knowledge of local Conservation Officers, and the experience of one employee to infer which predators had the greatest impact on GPAs. As noted in the aforementioned studies, striped skunk, red fox and raccoon were primary predators.

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[3]Rabenberg, M. J. 1984. First year report: nest dragging study, Waubay Wetland Management District. 24pp. Unpubl. report. Waubay Wetland Management District, USDI Fish and Wildlife Service, Waubay, South Dakota.

[4]__________, 1985. Second year report: nest dragging study, Waubay Wetland Management District. 41p. Unpublished report. Waubay Wetland Management District, USDI Fish and Wildlife Service, Waubay, South Dakota.

Use of vehicle tracks as travel lanes by predators was first suspected by L. Kirsch at NPWRC. Fresh sand spread in vehicle tracks on one study area in North Dakota showed higher use by red fox and striped skunk than plots located as far as possible from vehicle paths (NPWRC, unpublished data). Based on the relatively simple approach taken in my study, nest searching with vehicles may significantly reduce probability of survival of nests adjacent to or between vehicle tracks.

Lake Albert Island

Number, density and distribution of mallard nests on Lake Albert Island in 1985 were all comparable to those reported by Drewein and Fredrickson (1970). Those authors did not report fate of nests but noted no evidence of predation and only three abandoned clutches found during searches. Apparent nest success was lower on Lake Albert Island in 1985 (55 percent) and 1986 (34.2 percent) than the 60 to 90 percent reported as typical for island nesting dabbling ducks by Deubbert et al. (1983). In 1985, abandonment was the major cause of nest failure on Lake Albert Island, accounting for 71 percent of unsuccessful clutches. Duebbert et al. (1983) found no difference in rates of abandonment between years when searches were conducted during and after the breeding season, leading them to conclude that abandonment was due to natural behavioral interactions or physiological responses rather than investigator disturbance. In 1986, nest searching was delayed until well after peak hatching. Abandonment accounted for a lower proportion of failed nests (table 2), but increased predation was the primary cause.

The chief benefit of islands for upland nesting ducks is protection from mammalian predators (Townsend 1966, Duebbert 1982, Hines and Mitchell 1983). Lake Albert Island was trapped, through not intensively, each spring from 1980 through 1986. Occasional raccoon and striped skunk were removed. There is a red fox denning site on the island, and red fox were evicted from the island one spring. In spite of the annual (albeit limited) trapping effort on the island, predation by mammals was evident both years. Raccoon, woodchuck (Marmota monax) or mink (Mustela vison) were probably responsible for nest failures in 1986.

CONCLUSIONS

The North American Waterfowl Management Plan (1986) identified recruitment in prairie nesting ducks as the top priority problem facing waterfowl managers today. While duck nest success on GPAs far surpassed that on private lands (Johnson et al. these proceedings), the impact of predation on GPAs was great, especially for some areas and species. Even in 1986, a year of excellent habitat conditions, predation left duck nest success far below potential on GPAs. Intensive management (eg. nest structures, predator-free nesting islands, predator exclusion fences and predator removal) will be necessary to increase nest success and enhance duck recruitment on GPAs.

Lake Albert is well suited for intensive management. Potential production from successful nests on Lake Albert Island in 1985 was 265 ducklings. Brood rearing habitat in the area is in excellent condition due to high water levels and flooding of low-lying areas. Thorough trapping on Lake Albert Island is clearly justified.

Excellent nesting cover but low nest success on the Hogsback peninsula led SDGFP and Ducks Unlimited to construct a predator exclusion fence across the base of the peninsula in the fall of 1986. If high nest densities on the nearby island are one cause of observed abandonment, providing alternative secure nesting cover may allow more hens to nest successfully. Although nothing is known about duckling survival on Lake Albert, recruitment, survival and homing, or immigration are evidently adequate to maintain the population. I hypothesize an increase in nest density on the Hogsback over time as a result of predator exclusion.

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Increasing Waterfowl Production on Points and Islands by Reducing Mammalian Predation[1]

John T. Lokemoen[2], Richard W. Schnaderbeck[3], and Robert O. Woodward[2]

Abstract.--On 12 points, with electric predator barriers, there were 0.84 duck nests per acre with a hatching rate of 60%. On 12 control points, there were 0.23 nests per acre with a hatching rate of 8%. On 9 islands where predators were removed, there were 851 nests in 1986 with 87% nest success. In 1984 and 1985, before predators were controlled, these islands contained 52 nests with 8% nest success. The management cost to produce hatched young on treated points was $7.13 compared with $0.33 for each hatched young on islands.

INTRODUCTION

Recent studies of mallard (Anas platyrhynchos) mortality (Sargeant et al. 1984), hen success (Cowardin et al. 1985), and brood survival (Talent et al. 1983) have indicated severe losses of hens, eggs, and young to mammalian predators. As a result, biologists interested in managing breeding waterfowl have shown increased interest in regulating predation.

A study of waterfowl management methods (Lokemoen 1984) concluded that predator management was the most cost-effective technique to increase waterfowl production. Islands, where nests were separated from mammalian predators, were particularly beneficial to breeding waterfowl but islands were expensive to construct.

In this study we tried to create "safe nesting islands" for breeding waterfowl without using expensive construction methods. We used fences with electric wires to deter predators from points. These types of fences have been shown to reduce predator movement into nesting habitats (Forester 1975, Lokemoen et al. 1982). Also we attempted to increase waterfowl production on existing islands by removing mammalian predators. The point study areas were located in east-central North Dakota and the island study sites in northeastern North Dakota.

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[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop held at Howard Johnsons (Rapid City, South Dakota on April 28-30, 1987).

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METHODS

Five treated points were studied in 1985 and 7 in 1986. A similar number of control points located nearby contained no fences or predator control.

To create "safe nesting islands" we built wire fences across the base of points using 18 gauge 1-inch mesh poultry netting. The fence extended 5.5 feet above ground level (AGL) and 1 foot below ground level. The top 1 foot of the fence extended outward at a 45° angle. Fences extended into the lake 50-150 feet to water 2 feet deep. Two energized electric wires off-set 2.5 inches and 5.0 inches from the fence were placed on the outside of the fence 4 feet AGL. Another energized wire was placed 2.5 inches above the top of the poultry netting.

Mammalian predators were trapped within the fenced point exclosures using 220 conibear traps set in boxes. Sardines and dead fish were placed inside the boxes as bait. On 2 points, size 1.5 leg-hold traps were set to capture mink (Mustela vison). An average of 3.8 conibears and 0.5 leg-hold traps were set at each point. An average of 8 trips were made to each treated point to remove trapped predators and maintain the fence.

On islands, predators were removed after the ice melted in spring. Islands were walked to flush and shoot red fox (Vulpes vulpes) and traps and snares were set to remove other predators. An average of 3-110 conibears, 2-220 conibear traps, and 3 snares were set at each island. Predators were removed from 7 islands in the spring of 1986, and from 2 islands in Stump Lake during the springs of 1985 and 1986. An average of 4 trips were made to each island.

All treated points, control points, and islands were searched for waterfowl nests 2-4 times during the nesting season. Nest searches involved 2-6 people walking abreast and pulling weighted ropes or riding all terrain vehicles and pulling a 5/16" chain to flush waterfowl hens and locate nests (Higgins et al. 1977). Each nest was marked with a flag when found and nests were revisited to determine fate and count hatched eggs. Nest success was determined by the modified Mayfield method (Johnson 1979). Nest numbers, nest success, and the number of young hatched were compared between treated and control points and at islands before and after predator control.

Costs of ducklings were estimated by dividing the annual management expenses for establishment and maintenance by the number of young ducks hatched. Cost estimates were the same as those used by Lokemoen et al. (1984). Labor costs were set at $6.50 per hour and transportation costs at $0.33 per mile. All costs were prorated for the life of the practice using the Water Resources Council standard amortization rate of 0.08875.

RESULTS AND DISCUSSION

Paired Point Comparisons

Treated points contained 280 nests with 60% nest success compared with 39 nests and 8% nest success on control points (Table 1). An average of 128.8 young hatched during each of the 2 years on the treated points compared to 2.4 young hatched per control point. Gadwalls (Anas strepera) comprised 39% of the total nests on points, blue-winged teal (Anas discors) 25%, mallards 11%, and pintails (Anas acuta) 10%.

Predation on control points in central North Dakota was severe and few waterfowl nesting attempts were successful. Electric barriers plus predator control greatly benefited duck nesting success but did not fully stop predation. Several hens were killed by raptors and eggs were destroyed by American crows (Corvus brachyrhynchos), which fences do not deter. Eggs were also destroyed by mink and raccoon (Procyon lotor), some of which swam around the fence and were not captured in traps.

The species composition of 47 predators captured on points included raccoon 40%, striped skunk (Mephitis mephitis) 32%, red fox 21%, mink 2%, and Franklin's ground squirrel (Spermophilus franklinii) 4%.

Table 1.--Number of nests, nest success and nest density on treated (T) points with predator barriers and on control (C) points in central North Dakota, 1985 and 1986.

Year		N	Acres	No. of nests	Nests per acre	Nest suc. (%)	Total young hatched
1985	T	5	149	112	0.75	55	571
	C	5	65	16	0.25	11	18
1986	T	7	184	168	0.91	63	975
	C	7	102	23	0.23	5	11
Total or avg.	T	12	333	280	0.84	60	1546
	C	12	167	39	0.23	8	29

Island Comparisons

The number of nests found on islands increased from 52 before predator control to 851 after predator control (Table 2). Nest success rose from 8% before predator removal to 87% after predator removal. An average of 790.6 young were hatched on each island in 1986 after predator control compared to 4.7 young hatched per island in 1984 and 1985 before predator control.

The density of waterfowl nests increased rapidly from 0.7 to 11.8 nests per acre after predators were removed from islands. On the 2 large islands in Stump Lake, nest densities increased from 0.2 nests per acre in 1984 to 13.3 nests per acre in 1986, a 66.5-fold increase.

Mallards and gadwalls formed 93% of the island nesting population. These 2 species also initiated 93% of the nests on Miller Lake Island, North Dakota (Duebbert et al. 1983). A few blue-winged teal, northern pintail, and lesser scaup (Aythya affinis) also nested on the islands.

After predator control was initiated, most nest losses on islands were attributed to mink or crows. A total of 18 predators were captured on the 9 islands in 1986. The species composition of predators captured on the 9 islands was 44% red fox, 39% mink, 11% raccoon and 6% striped skunk. Red fox and mink were more frequently captured on islands compared to points and striped skunk and raccoon were less frequently captured.

Duck Production Costs

The average total cost of each fence was $5,964.96, which yields an annual cost of $650.18 when amortized over 20 years. This expense plus an estimated $267.75 yearly cost of fence maintenance and predator removal resulted in a total annual cost of $917.93 for each fenced point (Table 3). By dividing the total annual cost by the total annual production we obtain a cost of $7.13 for each young hatched.

The estimated cost to hatch a duckling on an island was $0.33. This cost was lower than the cost of ducklings hatched on points because there were no construction expenses and islands had higher nest densities and success. Major island expenses were transportation and labor involved in visiting islands for predator removal.

The cost per young would decline if the number of successful nests on the treated points and islands increased. Numbers of nesting ducks might increase because of homing by successful hens and their young (Sowls 1955). Nest success might also rise if managers increase trapping effectiveness.

These data were obtained during 2 field seasons and must be considered preliminary. The results indicate, however, that the 2 management schemes can be highly effective. The response of ducks to predator-reduced nesting environments was rapid and production was greatly enhanced in the first year. Estimated costs of hatched young were comparable to or lower than fledged young costs estimated by others.

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Table 2.--Number and success of duck nests found on 9 islands in 1984 and 1985 before predator control and in 1986 after predator control near Devils Lake, North Dakota.

Island Name	Size (a.)	Before: No. of nests	Before: Nest suc. (%)	After: No. of nests	After: Nest suc. (%)
North Salt	10	14	3	165[1]	61
Sheep	2	14	2	48[1]	86
McHugh	6	2	38	3[1]	36
Minnewaukan	5	5	10	19[1]	88
Pelican 1	2	2	19	21[1]	94
Pelican 2	2	4	19	31[1]	94
Calderwood	5	3	45	34[1]	83
Stump 1	25	5	-	293[2]	97
Stump 2	15	3	-	237[2]	95
Total or average	72	52	8	851	87

[1]Predator control conducted only in 1986.

[2]Predator control conducted in 1985 and 1986.

Table 3.--Estimated annual cost in dollars for management applications and for each duckling hatched on treated points and on islands with predator control in central North Dakota 1984-1986.

Activity	Points		Islands
	Annual Expenses		
Construction(fence)[1]	650.18	(None)	00.00
Transp.(400 mi)	$132.00	(184 mi)	$60.72
Labor (12 hrs)	78.00	(25 hrs)	162.50
Supplies (5 traps)[2]	7.75	(8 traps)[2]	11.63
Other (materials)	50.00	(Boat)[2]	25.83
Tot. annual costs	917.93		260.68
Avg. no. yg. hatched	128.8		790.6
Cost/yg. hatched	7.13		0.33

[1]Costs amortized over 20 years.

[2]Costs amortized over 10 years.

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Bullsnake Predation on Waterfowl Nests on Valentine National Wildlife Refuge, Nebraska[1]

Scott S. Glup[2] and Leonard L. McDaniel[3]

Abstract: Bullsnake (Pituophis melanoleucus) predation on upland nesting ducks was monitored on Valentine National Wildlife Refuge (NWR) from 1982-86. The fate of 1,999 duck nests of 9 species was observed under different treatments of land use and control of potential nest predators. Maximum potential levels of bullsnake depredation are masked by nest destruction by mammalian species; bullsnake nest depredation rates were >65% where mammalian predators were controlled, >40% without predator control and <4.0% where both mammalian and reptilian predators were controlled and/or excluded. Duck nest densities were dramatically increased where predator control was accomplished in undisturbed nesting cover.

INTRODUCTION

The major environmental factors contributing to positive waterfowl production include a complex of quality wetlands, dense nesting cover and rigid control of potential nest predators (Duebbert and Lokemoen, 1980). Extensive degradation of habitat is limiting the reproductive potential of waterfowl over their breeding range. Improving the productivity of remaining habitat is one means to counter the downward population trend of waterfowl.

In the early 1970's, a major change in management of wetlands and upland nesting cover was initiated on Valentine NWR. Seven lakes totalling 950 ha were mechanically dewatered and chemically treated to improve water quality by elimination of carp (Cyprinus carpio) infestations. Annual livestock grazing was reduced from 42,000 animal use months (AUMs) to approximately 13,000 AUMs by 1983. Timing of grazing treatments was used to create and maintain tall warm season grass species for nesting cover. Documentation of the response of waterfowl to the change in management direction has been monitored.

Ladd (1969) documented that the sub-irrigated meadows are the primary sites selected by upland nesting ducks on Valentine NWR. Nesting studies carried out during 1970-72 and 74 on 1,260 ha documented that average upland duck nest densities in undisturbed cover (0.6/ha) were double that found in disturbed cover. A greater disparity between undisturbed and disturbed cover nest densities was documented during 1978-82 on 1,658 ha. This information substantiated that upland nesting ducks preferentially selected nesting cover that had been undisturbed for two or more years over disturbed cover (0.8 vs. 0.2 nests/ha). Average mallard (Anas platyrhynchos) nest densities were eight times greater in cover that was undisturbed for two or more years than in any other cover treatment. Since 1980, "preferred" nesting cover increased from 9 to 41% of the total meadow classified priority management for upland nesting waterfowl.

Management strategies to increase waterfowl production on Valentine NWR by improving wetland quality and upland nesting cover have been dampered by excessive nest predation. Sargeant and Arnold (1984) listed the badger (Taxidea taxus), coyote (Canis latrans), Franklin's ground squirrel (Spermophilus frankinii), mink (Mustela vison), raccoon (Procyon lotor), red fox (Vulpes vulpes) and striped skunk (Mephitis mephitis) as predator species having the greatest impact on duck production. Except for the Franklin's ground squirrel and red fox, these predator species occur and have been documented as predators on duck nests on Valentine NWR. Teer (1964) documented long-tailed weasel (Mustela frenata) depredation on eggs of blue-winged teal (A. discors). Long-tailed weasels were documented preying on both eggs and nesting hens in our studies; however, depredations were infrequent, localized and easily controlled. Imler (1945) documented the bullsnake as a major predator of duck nests in the Nebraska Sandhills. Snake predation on waterfowl nests has been reported by others (Aldrich and Endicott 1984 and Wheeler 1984); however, the magnitude of its impact upon production is seldom addressed.

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Summarized are the preliminary results of efforts to increase waterfowl production by removal and/or exclusion of potential waterfowl nest predators. Emphasis is placed on bullsnake depredations and their control during 1982-86.

Fort Niobrara-Valentine NWR Complex staff and, in particular, refuge volunteers G. Ackerman, S. Kinnison, T. Krumwiede and R. Wingenroth provided field assistance. Appreciation is extended to M. Lindvall, J. Matthews, N.I. Peabody and L. Schroeder who reviewed and provided constructive comments and also J. Edwards who typed the manuscript.

STUDY AREA AND METHODS

Valentine NWR is located in the north central portion of the Nebraska Sandhills, 16 km south of Valentine, Nebraska. The refuge totals 28,955 ha including approximately 4,000 ha of marsh and shallow lakes, 20,000 ha of sand and choppy sand sites and 5,000 ha of sub-irrigated meadows.

Control of nest predators was initiated in 1982 on Habitat Unit (H.U.) 18C2; an island which was reduced from 27 to 4 ha during the 5-year study period by rising water levels of the Marsh Lakes. In 1985, control efforts were expanded to the Marsh Lakes proper which includes 930 ha of wetlands, 540 ha of meadow and 2,050 ha of sand and choppy sand sites. Documentation of the mainland control effort was concentrated in H.U. 21B-18C1; a 40 ha area of undisturbed nesting cover where duck production potential was high. Duck nests were located and monitored within the parameters of Klett et al. (1986), Reardon (1951) and Imler (1945).

Force account mammalian control activities were conducted during March-May to remove resident predators (Roy and Dorrance 1985) which remained after the opportunity for harvest was available to recreational hunters and trappers. Conibear, live and leg-hold traps as described by Johnson (1983), Wade (1983), Boggess (1983), Knight (1983) and Henderson (1983) were used to capture mammalian predators. Drift fence traps were used to capture bullsnakes (Imler 1945 and Buford 1983), but, the entrance of the funnel opening into the trap was reduced to 25 mm in diameter to minimize capture of non-target species. Electrical fencing (Lokemoen et al. 1982) was used from 1982-84 to prevent mammalian predators from gaining access to H.U. 18C2 via dike; however, it was discontinued in 1985 because of inundation of the dike by high water. In March of 1985-86, coyotes were removed by aerial hunting (Wade 1978).

RESULTS AND DISCUSSION

A total of 1,999 upland duck nests including 7 dabbling and 2 diving duck species were monitored during 1982-86. In 1983-84, Glup (1986) found that the nest densities were greater (P<0.0810) in undisturbed cover (1.3 nests/ha) than in grazed cover (0.5 nests/ha). Also extensive duck nest destruction occurred in all cover treatments. Coyotes and bullsnakes destroyed 68% of all nests under observation and 96% of all nests destroyed by predators.

Duck nest destruction by mammalian predators was significantly less in areas where control techniques were applied as compared to areas where control was not carried out. The percentage of nests destroyed by mammalian predators other than coyotes and number of these predators taken both increased after intensive coyote control was initiated (table 1). In the absence of mammalian predation, bullsnake depredations increased to >65%. Thus compensating for nest depredations that otherwise would have been incurred by mammalian species (fig. 1).

Table 1. Potential mammalian predators removed prior to and during the nesting season.

Species	1982	1983	1984	1985	1986
Coyote	1	56	33	175	82
Other[1]	6	33	20	43	56

[1]Other includes raccoon, skunk, mink and badger.

Bullsnake nest predation is generally subtle, occurring over a period of time. Bullsnakes consume 1-5 eggs per visit. Rarely did we document cold eggs in abandoned nests being taken. Also, spoiled eggs in nests being incubated were not taken by bullsnakes. During 1982-85, 110 bullsnakes were removed from H.U. 18C2. Twenty-eight were captured in duck nests consuming or attempting to consume eggs, and in seven instances the hens were

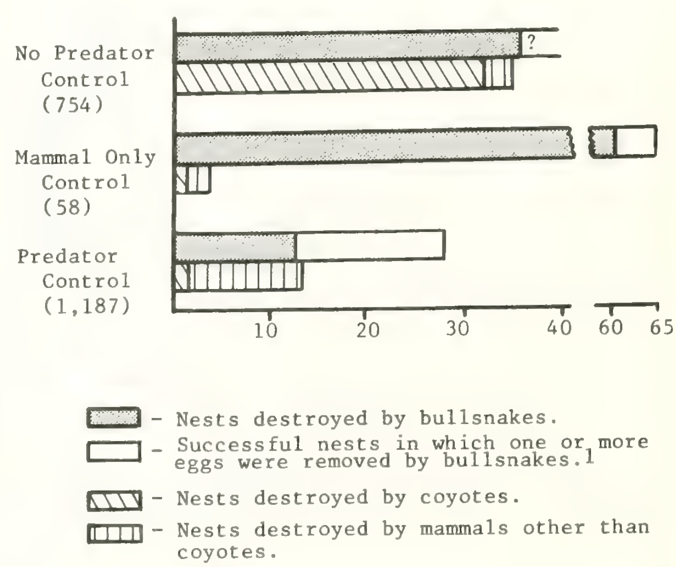

Figure 1. Percent duck nests depredated comparing three predator control management strategies.

[1]? - Information lost in a residential fire.

still on the nests. Bullsnake predation is not limited to eggs, small ducklings may also be taken. In 1985, a 122 cm bullsnake was observed and photographed that had captured a nesting green-winged teal (A. crecca).

Imler (1945) reported that of 274 duck nests under observation on Crescent Lake NWR, bullsnakes completely destroyed 114 (45%) besides taking eggs from many other nests. Bullsnake depredation does not always result in termination of the nest (fig. 1). Although nesting attempts may be defined as successful, clutch sizes are reduced. The mean number of eggs hatched from 345 blue-winged teal nests was 9.6 per normal nest and 6.1 per nests depredated by bullsnakes. Whereas, for 202 mallard nests, 8.2 eggs hatched per normal nest and 6.0 eggs hatched per depredated nest.

Bullsnakes present differential rates of predation on early and later nesting species or individuals depending upon the timing bullsnakes emerge from hibernacula (fig. 2). Glup (1986) found a statistically significant linear decrease ($R^2 = 0.9246$, $P<0.0001$) in nest success during the 1983-84 nesting seasons. During 1985-86, average bullsnake depredation rates on mallards were considerably less than later nesting gadwall (A. strepera) and blue-winged teal (table 2).

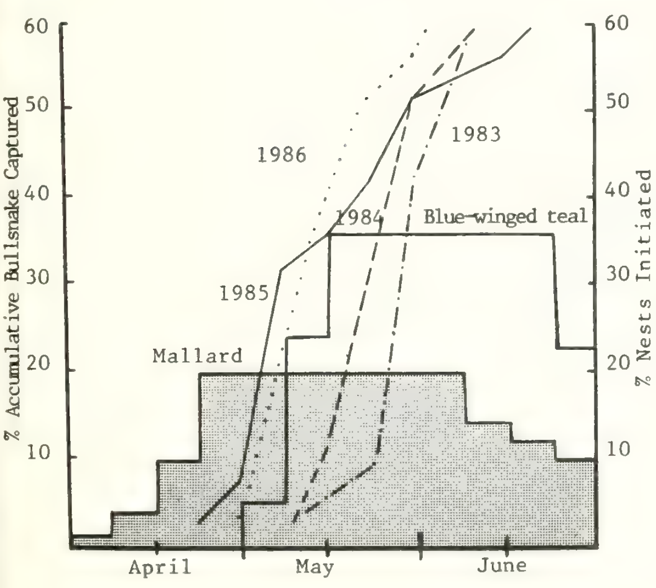

Figure 2. Date bullsnakes emerged from hibernacula in relationship to mallard and blue-winged teal nesting chronology -- 1983-86.

Table 2. Average bullsnake predation rates for duck nests under observation -- 1985-86.

Species	Nests	% Bullsnake Depredation	% Bullsnakes Destroyed
Mallard	249	12.5	7.6
Blue-winged teal	426	34.0	22.3
Gadwall	114	33.0	19.0

Bullsnakes have generally been considered sedentary in nature (Imler 1945, Fitch 1949 and Parker and Brown 1980), but, Fox (1986) reported activity ranges of 4-17 ha for bullsnakes on Crescent Lake NWR. Telemetry studies on Crescent Lake NWR substantiated that bullsnakes do not communally den in the Nebraska Sandhills, but, rather individually use pocket gopher (Geomys bursarius) burrows extensively throughout the year. Therefore, limiting present known options of bullsnake control to intensive trapping.

A total of 658 bullsnakes were captured with 1,242 m of drift fence traps in 1985. In 1986, 786 bullsnakes were captured with 2,985 m of fence. Population densities of bullsnakes on Valentine NWR are unknown; however, the number of bullsnakes captured exceeded duck nests located on the study area where intensive predator control was initiated in 1985. A trapping effort of 7.5 m of drift fence traps per 0.4 ha reduced bullsnake depredation on duck nests by 21% and nest destruction by 12% (Table 3).

Table 3. Bullsnake control and waterfowl productivity -- H.U. 21B-18C1.

Year	Bullsnakes Captured[1] #	Bullsnakes Captured[1] #/ha	Duck Nests #	Duck Nests #/ha	Bullsnake Depredation % Nests Depredated	Bullsnake Depredation % Nests Destroyed
1985	409	10.1	194	4.8	49	27
1986	319	7.9	146	3.6	28	15

[1]Does not include hatchlings.

Greater success in reducing duck nest depredation by bullsnakes was achieved in H.U. 18C2. Bullsnakes gain access to this island from the mainland by swimming less than 100 m. Predator control activities were intitiated on H.U. 18C2 in 1982; however, bullsnake numbers and depredations were not suppressed until intensive trapping was accomplished on the adjacent mainland during 1985-86 (table 4).

The management strategy applied to H.U. 18C2 during the five years provided an environment favoring mallard production. From 1982-86, mallard nests increased from 13 to 114 while blue-winged teal nests decreased from 117 to 31. Low return rates of blue-winged teal (Sowls 1955) evidently prevented them from responding similarly to mallards even though high nest success was achieved (table 4).

Table 4. Bullsnake control and effect upon duck production - H.U. 18C2.

Year	Duck Nests/ Ha	Bullsnakes Captured	Bullsnake Depredations % Nests Depredated	% Nests Destroyed	Mayfield Nest Success
1982	5.2	28	40	16	33
1983	8.4	30	23	7	75
1984	29.1	32	38	23	43
1985	40.8	12	12	3	67
1986	44.5	8	6	1	69

Productivity resulting from a management strategy that emphasized environmental factors which contribute to positive waterfowl reproduction ranged from 21.7 ducklings per ha on the mainland to 232 for the island study areas. Conversely, strategies applied to these same areas in the past in which one or more of the major environmental factors for positive production were lacking, productivity ranged from 1.0 to 2.3 ducklings per ha.

MANAGEMENT IMPLICATIONS

There are excellent opportunities for increasing waterfowl productivity on lands dedicated to that purpose. However, management needs to focus on practical strategies which are physically possible and therefore long-term in nature -- attitudes and historical priorities may also need to be reassessed.

Degradation of wetland quality, lack of adequate nesting cover and excessive nest predation are the primary obstacles confronting nesting ducks. Where these environmental factors were addressed on Valentine NWR, high duckling productivity was realized. Duck nest success and density were both significantly increased especially for those species with strong homing tendencies such as the mallard.

An effective nest predator control program needs to include all potential nest predator species. Predator control can be most efficiently carried out with an intensive effort immediately prior to and during the nesting season. The bullsnake is an extra element, evidently unique to the Nebraska Sandhills, which complicates an effective and efficient nest predator control effort. Presently, refuge-wide duck nest predator control is not practical; therefore, intensive management is being limited to areas with potential for high duck production.

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Overwater Nesting by Ducks: A Review and Management Implications[1]

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Abstract.--Nest success of overwater duck nests is generally higher than nests in upland sites. A review of the literature indicated that the major factors limiting success of overwater nests were fluctuating water levels, nest parasitism, predation, and human disturbance. Regional patterns of the occurrence of these factors could not be discerned. General management guidelines for improved recruitment and reduced nesting female mortality are suggested.

INTRODUCTION

Waterfowl that nest over water, including most species of diving ducks, will be the focus of this review. Man-made nesting structures placed overwater have improved nest success and production of several species of dabbling ducks, but are not within the scope of this review. Therefore, our objectives were to review representative nesting studies and compile information regarding limiting factors that have been suggested for overwater nesting ducks. Based on these factors, general management guidelines to improve recruitment and reduce nesting female mortality of overwater nesting waterfowl are presented.

LIMITING FACTORS

On a comparative basis, fluctuating water levels during the nesting season can be more disruptive to overwater nesters than to upland nesters. Nest success of overwater nests is often high (>50%), but have been reduced to 10% or less by fluctuating water levels (C. C. Evans and D. E. Sharp, unpubl. data). While some upland nests in low-lying areas may be susceptible to flooding, nearly all overwater nests are affected by water level fluctuations. Water level changes, as little as 10-15 cm over a few days, may be sufficient to cause adverse effects. Low levels reduce the water barrier and allow easier access by mammalian predators into the marsh, and thus increase the susceptibility of eggs, nesting females, and broods to predation (Stoudt 1971). Female diving ducks may be more susceptible to predation than dabbling ducks when low levels isolate nests, because they have more difficulty getting airborne from dry surfaces than water. Low water levels can also result in increased egg parasitism or nonbreeding (Olson 1964). High water can inundate nest cover (Joyner 1975) and (Mendall 1958). If residual cover is flooded early in the nesting season, females may be forced to nest in lower quality sites or forego breeding entirely. Nests in flooded residual cover are more susceptible to avian predators (Joyner 1975). Record high water levels at Ruby Lake National Wildlife Refuge (NWR), Nevada, flooded nesting cover in 1984-85. During this period, canvasbacks (*Aythya valisineria*) and redheads (*A. americana*) were found to have a reduced breeding effort, lower nest success, and an increase in the incidence of egg parasitism by redheads (C. C. Evans, unpubl. data).

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The incidence of parasitic egg laying is generally confined to overwater nests and upland nests that are close to water (Joyner 1975). Although several species of ducks are known to lay eggs in the nests of other ducks, this type of parasitic behavior is most commonly reported for redheads and ruddy ducks (Oxyura jamaicensis). In some areas, the incidence of parasitic egg laying on overwater nests can be very high, as Weller (1959) trapped 13 different redheads at a single canvasback nest. Host clutch sizes are usually reduced by egg displacement that can occur when parasitic females attempt to lay eggs in a nest with the host female present. Olson (1964) reported an average of 15.4 redhead eggs in canvasback nests, while host eggs averaged 3.9. A large number of parasitic eggs may also reduce host clutch size by suppressing ovulation, or may cause the host to abandon the nest (Weller 1959).

Predation can limit productivity of overwater nesting waterfowl (Table 1). Nesting overwater restricts access by most mammals especially canids and skunks (Mephitis mephitis) which are major predators of upland nests and nesting females. Sargeant et al. (1984) found that diving ducks were taken by red foxes (Vulpes vulpes) less frequently during the nesting period than dabbling ducks. In North Dakota nest success of mallards (Anas platyrhynchos) nesting overwater was higher than those nesting in upland sites (Krapu et al. 1979). Mink (Mustela vison) and raccoons (Procyon lotor), which are less hampered by water, are major predators of overwater nests and nesting females (Eberhardt and Sargeant 1977, Sayler 1985,). Predation by gulls and corvids is not similarly affected by a water barrier, but seems to be more affected by visual obstruction of vegetation than mammalian predators. Most avian predation occurs when nesting females are not attending the nest (Dwernychuk and Boag 1972a, Bourget 1973). Waterfowl nesting near larid colonies can have both positive and negative effects on nest success. Nesting near colonies of terns and small gulls can increase nest success as larids keep corvids out of the colony, thus reducing loss of waterfowl eggs. However, this benefit can be offset by gull predation on ducklings (Dwernychuk and Boag 1972b), as large gulls can prey on both eggs and ducklings.

Quality and quantity of the vegetation used for nesting can affect the vulnerability of nests to predation. Nesting cover conceals nests from visual-oriented predators, such as birds. Dwernychuk and Boag (1972a) found an inverse relationship between amount of cover and number of eggs lost from simulated nests. Where cover was thinned by flooding, 67% of the overwater nests were destroyed by gulls, while in an adjacent marsh not similarly affected by flooding, only 4% of the overwater nests were lost to gulls (Joyner 1975). Conversely, for scent-oriented predators, cover functions as a physical barrier that reduces search speed and efficiency. Bowman and Harris (1980) found no difference in proportion of partially and totally concealed nests found by raccoons in laboratory tests. However, the raccoons found fewer nests when the cover was spatially complex. Where predator populations are low, nest success can be high even with low quality cover (Steel et al. 1956). Where predator populations are high, dense, good quality cover will not provide sufficient protection from predation (Stoudt 1982, Krasowski and Nudds 1986). Much of this problem is the result of the concentration of both predators and prey into smaller and smaller islands of habitat. Agricultural activities and changes in the natural predator community, including a reduction or elimination of wolves (Canis lupus) and coyotes (C. latrans), have allowed red foxes and raccoons to increase their ranges and densities (Stoudt 1982).

High density overwater nesting cover functions to provide protection from predation, egg parasitism, human disturbance and effects of wind or waves. Preferences by overwater nesters for species composition and density of nesting cover has been found to vary among areas. High density nesting by canvasbacks and redheads at Ruby Lake NWR were found hardstem bulrush (Scirpus acutus) with densities of 300-430 stems of residual cover per m^2 (S. H. Bouffard, unpubl. data).

Distribution of nest cover is also important. Female diving ducks usually nest near patches of open water. Steel et al. (1956) found 97% of all diving duck nests were within 14m of open water. At Ruby Lake NWR the mean distance from diving duck nests to open water was 7.5m (S. H. Bouffard, unpubl. data). High interspersion of nesting cover with open water increases the area available to nesting ducks. Weller and Spatcher (1965) recommended a 50:50 ratio of open water:emergent vegetation. At Ruby Lake NWR prime nesting areas were composed of 53% emergent vegetation, 31% open water, and 16% upland. Canvasback nest densities at Ruby Lake NWR are generally high, often exceeding those of the Prairie Pothole Region of southern Prairie Canada. Olson (1964) speculated that selection of small ponds or open water areas within areas of prime nesting cover by nesting canvasbacks reduced parasitism; searching the peripheral cover of small ponds and openings by parasitic redheads was not cost effective in terms of time and energy expenditures.

Human disturbance can have adverse impacts on recruitment of overwater nesting waterfowl. Detrimental effects of human activity on nesting have been reported by Jahn and Hunt (1964) and Keith (1961) and on broods by Beard (1953). Mendall (1958) documented increased waterfowl

Table 1. Comparison of nest success of overwater nests among several studies from various locations in North America.

Species	Location[1]	Date	Percent Nest Success[2]		Limiting[3] Factors	Source
Ruddy duck	IA	1939+	A	73	1,2	Low 1941a
Redhead			A	56-73	1	Low 1941b
Mallard	ND	1974-77	M	54	2	Krapu et al. 1979
Canvasback	MB(potholes)	1959-61	A	21	1,2,4,5	Olson 1964
	(large marsh)		A	29		
Canvasback		1977-80	A	67	2,4	Sayler 1985
Redhead			A	50	2,4	
Canvasback		1961-72	A	45	1,2,4,7	Stoudt 1982
Canvasback	AB	1952-65	A	36	1,4,5	Smith 1971
Redhead			A	52		
Ruddy duck			A	64		
Canvasback	SK	1952-65	A	65	2,4,5	Stoudt 1971
Redhead			A	52		
Ruddy duck			A	60		
Canvasback		1971-75	A	44	5	Sugden 1978
Ring-necked duck	ME(1st nests)	1943-55	A	70	2,3	Mendall 1958
	(renests)		A	61		
Redhead	PQ	1969-72	M	93	None	Alliston 1979
Canvasback	OR	1942,46-47	A	43	2,6	Erickson 1948
Redhead	ID	1949-51	A	85		Steel et al. 1956
Ruddy duck			A	56	1,3	
Canvasback			A	67		
Redhead	MT	1960-61	A	15	6,7	Lokemoen 1966
Redhead and ruddy duck	UT	1967	A	100	None	McKnight 1974
		1968	A	74	6	
Ruddy duck	CA	1952	A	32	2	Rienecker and Anderson 1960
Redhead			A	45		
Ruddy duck		1957	A	69		
Redhead			A	88		
Canvasback	NV(Ruby Lake NWR)	1972,77-83	M	69	2,6,7,8	S. H. Bouffard, C. C. Evans, and D. E. Sharp, Unpubl. data
		1984-85	M	13,10		
Redhead		1972,77-83	M	68		
		1984-85	M	5,20		

[1]State/Province abbreviations: IA = Iowa; ND = North Dakota; MB = Manitoba; AB = Alberta; SK = Saskatchewan: ME = Maine; PQ = Quebec; OR = Oregon; ID = Idaho; MT = Montana; UT = Utah; CA = California; NV = Nevada.

[2]Nest success calculations: A = apparent nest success; M = Mayfield nest success.

[3]Limiting factors (not in order of importance): 1=nest desertion; 2=water level fluctuation; 3=predation; 4=mammalian predation; 5=avian predation; 6=parasitism; 7=human disturbance; 8=inclement weather.

production following a closure of boating on Moosehorn NWR. Studies in the early 1970's at Ruby Lake NWR prompted a closure of boating during peak nesting of canvasbacks and redheads (USFWS 1976). Flushing females off nests by humans can increase vulnerability of the eggs to avian predators.

It has been shown that fish can have negative impacts on waterfowl recruitment. Fish, nesting female ducks, and ducklings function as predators of macroinvertebrates. Macroinvertebrates are necessary for egg production in ducks and growth of ducklings. Reduction of invertebrate numbers by fish and its negative impact on waterfowl production and distribution has been reported (Eriksson 1979, Eadie and Keast 1982, Pehrsson 1984). Carmichael (1983) documented dietary overlap of introduced game fish and diving ducks at Ruby Lake NWR. Canvasback clutch size at Ruby Lake NWR is lower than other marshes (Bouffard 1983) and canvasback duckling growth rates are slower than reported elsewhere (80-90 days to fledging: S. H. Bouffard, unpubl. data). This suggests that impacts of competition by fish may be occurring.

Review of several studies revealed that water fluctuation, predation and disturbance were important limiting factors in the west, in the pothole area and in the northeast (Table 1). Nest parasitism was a common limiting factor in the pothole area and in the west where redheads and ruddy ducks were common (Table 1). Overall, we concluded that differences in factors affecting nest success were site specific, and that no regional patterns existed.

Management Implications

When water control is possible, the maintenance of relatively stable marsh levels during the nesting season (April-June) is the single most important management practice for increasing recruitment. During the nesting season water levels should not fluctuate more than 10-15 cm. Slowly dropping levels are preferable to rising levels. After nests have hatched, water levels can be allowed to fluctuate with the natural regime, or with desired management objectives.

Vegetation management should be directed at maintaining dense, but highly interspersed cover, with 30-50% open water to 50-70% emergent nesting cover ratio. The assimilation of local information on nest success and cover utilization is fundamental in developing sound vegetation management practices, because the density and species of emergent vegetation used for nesting varies among areas. Manipulation of vegetation by water level control may involve trade-offs related to the incompatability of maintaining stable levels during the nesting season.

Various management practices can be used to manipulate cover: water interspersion. Of these, fire should be used cautiously. At Ruby Lake NWR, 2 years were necessary for the residual nest cover to return to its preburn density; no overwater nests were found in burned areas during the 2 years (S. H. Bouffard, unpubl. data). Bray (1984) found similar recovery rates for residual nest cover in Utah. Therefore, we suggest that burning can be used as a management tool, but should be used sparingly and in small blocks.

Fishing, boating, and other recreational activities should be curtailed on nesting marshes from April through August. Nesting females have been shown to be extremely sensitive to human disturbance during nesting. Although limited information exists on the impact of disturbance on duckling survival, preliminary information suggests that important brood areas should also be protected from high levels of human intrusion (D. E. Sharp, unpubl. data). Overwater nesters are particularly vulnerable to these types of disturbances because of their dependence on aquatic habitats for nesting, feeding, and brood rearing.

Fish have been shown to compete with waterfowl for food and have negatively affected waterfowl populations. The presence of fish increases the demand for fishing and introduction of bait fish-farming which increase human disturbance. Fish should not be introduced into marshes that are primarily managed for waterfowl.

Predator control has been shown to be cost effective and has increased recruitment of upland nesting waterfowl (Balser et al. 1968, Deubbert and Lokemoen 1980, Lokemoen 1984). Predator control increased egg hatch rates and improved chick survival of whooping cranes (Grus americana) at Grays Lake NWR (Drewien et al. 1985). Practices that exclude predators from ground nesting birds, such as electric fences (Lokemoen et al. 1982) have not been tested for diving ducks. Where predation has been shown to limit diving duck production, we recommend that carefully designed studies that evaluate predator exclusion or removal be initiated before extensive predator control programs are implemented.

Management guidelines that we propose are general concepts designed to improve production and reduce the effects of factors limiting recruitment of overwater nesting ducks. These practices may not complement efforts to improve production of upland nesting waterfowl, other

wildlife species, or for management of wintering or migration areas. Wetland managers will have to tailor these concepts to specific areas using local information and integrate management practices for overwater nesting waterfowl with other wildlife objectives. Finally, we strongly recommend that managers carefully design and execute a biologically sound monitoring program to evaluate management practices that are implemented.

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Distribution and Impact of Canada Goose Crop Damage in East-Central Wisconsin[1]

James W. Heinrich and Scott R. Craven[2]

ABSTRACT: Near Horicon marsh, in east-central Wisconsin, increasing fall concentrations of Canada geese (Branta canadensis) have produced many opportunities, and a few difficult problems. The problem of crop depredations has plagued the Horicon area since the mid-1960's and has resulted in many changes in goose management in Wisconsin.

A lack of basic data on the attitudes and concerns of Horicon area farmers hindered resolution of the crop depredation issue. In 1985 the Wisconsin Canada Goose Survey was conducted to address this need. A random sample of the 5,960 area farmers received the questionnaire in the mail early in 1986. Two more mailings encouraged those who had not responded to make their opinions known. Eighty-two percent of the sample ultimately returned a usable survey. This reflects responses from 11% of the area's farm population.

Generalizing from the survey data, Horicon area farmers perceived a 1.6 million dollar loss to Canada geese in 1985, mainly in alfalfa, winter wheat, and standing corn. The farmers did not feel that they were able to prevent unacceptable losses, even with the help of propane cannons and other abatement devices supplied by the agencies. They felt that changes in hunting laws and the managed increase in goose numbers had increased their crop losses. The farmers of east-central Wisconsin said that there are too many geese, and they called for a reduction in the flock.

The concerns of Wisconsin's farmers need to be addressed before further growth in the Mississippi Valley Population of Canada geese is approved. The survey results suggested that economic incentives for goose management could make the flock more attractive to farmers. If the value of the flock warrants it, these should be considered. In 1986 we began to examine the economic benefits that the Canada goose flock brings to east-central Wisconsin. Survey information from the local business community, the tourists who came to view the geese, and goose hunters will allow a better assessment of the economic impact of MVP Canada geese in east-central Wisconsin.

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Should Ducks Be Frightened?[1]

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Abstract.--The most common method of resolving waterfowl depredations to small grains is to scare ducks using mechanical scare devices or pyrotechnics. Scaring techniques, however, cause waterfowl to damage, by trampling, up to twice the amount of grain consumed. Conditions such as weather, harvest stage, cultural techniques, farm equipment, length of damage season, availability of alternative feeding sites, and waterfowl population could combine to increase trampling losses. These conditions should be evaluated to determine if large scale scaring projects may actually increase damages to small grains.

INTRODUCTION

Waterfowl depredations to small grains, wheat and barley have been a chronic and common problem in North Dakota since the 1930's. The problem occurs when large concentrations of southerly migrating waterfowl move into an area of unharvested grain and begin feeding. The practice of swathing, cutting grain into windrows to dry before harvesting, instead of straight combining increases the susceptibility of the small grain to waterfowl depredations.

Depredations were identified in the 1950's as being a limiting factor in waterfowl production (Munro and Gollop 1955). As a result, the U.S. Fish and Wildlife Service (FWS) began a large scale project to scare ducks from unharvested small grain fields. Various combinations of mechanical scare devices and pyrotechnics were used to frighten ducks. Waterfowl proved easy to frighten using the usual scare devices, but a question arose as to whether this project would increase or decrease damages.

METHODS

Data were collected over a five-year period, 1975-1980, and evaluated to determine if a statewide scaring project would reduce losses to small grain farmers caused by waterfowl. Observations were made by field personnel to record the number of days ducks were in a field, the number of fields damaged in an area and to estimate trampling losses. These data were used to evaluate the effectiveness of the project to reduce losses in an area.

A large quantity of scare devices were built, collected and distributed throughout the state. Mechanical scaring devices and pyrotechnics used in this study were: propane exploders, black plastic flags, firearms, 15mm flare pistols, racket bombs, whistle bombs, noise bombs, cracker shells and M-80 type bird bombs. Exploders and pyrotechnics were purchased from a national distributor and flags were built by YACC crews according to specifications established by the FWS (Duncan 1979). Approximately $10,000 of Animal Damage Control (ADC) operational and maintenance funds were expended each year for the purchase and construction of this equipment.

All of these devices were built or purchased by August 1 of each year. Mechanical scaring devices and pyrotechnics were distributed to farmers through ADC field stations and National Wildlife Refuge offices in North Dakota. Farmers were issued equipment after providing information on location of complaint, bird species involved and type of crop damaged. Farmers were also required to sign a liability release before bird bombs were issued. Farmers were not required to obtain a Federal Scare Permit.

ADC personnel conducted demonstrations throughout the state in which scare devices were provided, installed and waterfowl frightened from a field. The demonstration was also used to train neighboring farmers in waterfowl hazing techniques.

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[1]Paper presented at the Eighth Wildlife Damage Control Workshop, Rapid City, South Dakota, April 28-30, 1987.

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RESULTS AND DISCUSSION

In 77 percent of the complaints reported between 1975-1980, ducks were allowed to feed in a field for two days or less before being observed by the landowner or ADC personnel. Mechanical scare devices or pyrotechnics were utilized to frighten the birds from a field. The birds would then select and start feeding in another field and the sequence would be repeated. In 1980, near Devils Lake, ND, a flock of ducks was frightened nine times in a 20-day period. The results were nine irate landowners and a great deal of damage to nine fields due to trampling, feeding and contamination by defecation. In the Mud Lake area during 1979, five complaints were received concerning the same flock of birds over a ten-day period. During 1978 in the Kulm area, approximately 80 complaints were received involving four flocks of ducks in a 20-day period. In some cases, ducks had only alighted in a field before being frightened while, in other cases, ducks were in the field one to two days (Duncan and Zahn, pers. comm.).

In situations such as these, observations indicated waterfowl cause more damage to small grains by trampling than by eating. Sugden and Goerzen (1979) indicated ducks trample twice the amount of grain consumed and that most trampling damage occurs before a field is 30 percent utilized. Moving ducks every two days or less results in maximum trampling damages.

Observations from this study indicated there were several factors which should be considered before a large scale scaring project is implemented. We found that the critical element for success of such a project was the presence of an acceptable alternative feeding site into which ducks could be chased. If an acceptable alternative feeding site did not exist, the scaring project produced limited results because ducks simply continued to enter and cause extensive damage, by trampling, to additional unharvested fields. Observations indicated the most common alternative feeding sites were harvested grain fields, also called stubble fields. Early in the damage season when the harvest is less than 50 percent complete, few stubble fields or alternative feeding sites existed.

The long range weather forecast should be carefully examined to determine the extent that harvest may be delayed. This harvest delay determined the length of the damage season. Observations indicated that in years with a damage season longer than 30 days, harvest was minimal and scaring techniques produced limited results due to a lack of available alternative feeding sites. Scaring techniques did produce good results in short damage seasons, especially if the short damage season overlapped with waterfowl hunting season.

Observations indicated that scaring small bunches of birds may concentrate waterfowl in an area undiscovered by the landowner resulting in severe damages in a short period of time. Population surveys were used to monitor numbers of birds in an area, locate waterfowl concentrations and to record damage sites not previously reported.

Local cultural practices should be identified before a scaring project is initiated. For example, areas in which chisel plowing is predominant will produce better results from scaring projects than will areas in which molboard plowing is dominant because chisel plowing leaves more stubble and waste grain exposed. Areas which have a high incidence of grain dryers will have a shorter harvest season and, subsequently, a shorter damage season which will increase the effectiveness of scaring techniques.

Analysis of these factors indicated that the lack of alternative feeding sites, an extended damage season, a high population of ducks in the area during the damage season and local cultural practices could combine to reduce the effectiveness of a scaring project by encouraging waterfowl to feed in additional unharvested fields. By feeding in a large number of unharvested fields, ducks cause a great deal of trampling damage in an area. Large scale scaring projects can be effective, however, during a short damage season and if local agricultural practices produce an alternative feeding site.

Obviously, scaring ducks will not cause as much damage to an individual field as allowing the birds to feed unmolested in that field for the duration of the damage season. The benefits to the entire area, however, are diminished when birds are moved from one unharvested field to another every few days because combined trampling losses will increase. Scaring projects would, therefore, produce good results in individual fields, but less overall damage would occur in an area if the birds were allowed to feed in the originally selected field, thereby eating previously trampled grain. Unfortunately, no landowner will willingly accept damages over an extended period of time in the interest of an overall reduction of damages in the area because his individual losses would be high.

When the situation exists of an extended damage season, lack of alternative feeding sites and an unwillingness on the part of the landowners to accept high losses, a large scale scaring project may, in fact, cause more damage than it prevents. In this situation, it may be advantageous to utilize an alternative method of control whereby a lure crop is purchased and waterfowl allowed to feed in an unharvested field of their choice. Waterfowl from adjacent areas are encouraged to use the lure crop through the use of scare devices placed to protect nearby fields. By allowing waterfowl to concentrate and feed in one field for the duration of the damage season, overall losses in the surrounding area can be reduced.

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The Lure Crop Alternative[1]

Steven D. Fairaizl and William K. Pfeifer[2]

Abstract.--Lure crops are proposed as an alternative to scaring waterfowl. The lure crop works on the principle of permitting waterfowl to feed undisturbed for the duration of the damage season in an unharvested field of their choice thereby utilizing trampled grain. Waterfowl from adjacent areas are encouraged to use the lure crop through the use of scaring devices placed in protected fields. General criteria for implementation of a lure crop project and specific criteria for lure crop purchases are presented. Factors contributing to a successful lure crop and problems which reduced lure crop effectiveness are identified. Benefit/cost analysis of lure crops was completed.

INTRODUCTION

The conflict between waterfowl and North Dakota farmers was recognized around 1905 when the prairies were plowed and seeded. The problem escalated in 1936 when the marshes of Lower Souris National Wildlife Refuge were restored. By 1939 an estimated 200,000 ducks were present on the refuge and severe depredations to shocked grains occurred (Hammond 1961). Numerous isolated instances of depredations, such as these, occurred in the early 1900's but not until the mid-1940's did they generally become widespread. The problem intensified during the war years because of an inadequate supply of ammunition, fewer people hunting less than in normal times, gas, tire and auto rationing, shortage of farm help during the harvest season, cultivation of increased acreages of marginal and submarginal lands, and the rising prices of commodities (Day 1944).

Literature reviews indicated waterfowl depredations to small grains were caused primarily by one or more of the following factors: delayed spring planting, reduced plant growth rate, or wet fall weather conditions. The agricultural practice of swathing grain, instead of straight combining, increased the vulnerability of crops to waterfowl damage.

Depredations continued into the 1950's when the problem was termed a limiting factor in waterfowl management (Munro and Gollop 1955). An anti-duck sentiment began developing in the North Dakota agricultural community and farmers threatened to take matters into their own hands. For example, organizations such as the Souris Duck Control Association were formed to deal with the depredation problem. This organization advocated compensatory legislation, duck sterilization, population reductions and wetland drainage. In an attempt to curb these threats, the U.S. Fish and Wildlife Services (FWS), in the 1950's, began scaring ducks from unharvested small grain fields (Hammond 1950)[3]. Scaring produced limited results in the early part of the damage season or during severe damage seasons because alternative feeding sites into which birds could be chased were minimal. Furthermore, scaring birds from field to field caused inefficient food utilization and increased trampling damages.

Scaring was supplemented by feeding stations established on refuges. The stations worked well in reducing depredations as long as weather conditions allowed vehicle access to maintain a sufficient daily food supply. These two techniques were extensively utilized until the early 1970's.

Due to the limited effectiveness of these projects, the agricultural community requested a study of new approaches for resolution of the problem. Consequently, a three-year lure crop pilot study was established in 1975 to be tested in Bottineau, Nelson and Ramsey Counties of North

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Dakota. In subsequent years the study was expanded to include the entire state and extended until three years of usable data had been collected.

The basic concept of the lure crop technique was to purchase the crop in a field which had been selected by the birds and where a feeding pattern had been established, thereby allowing birds to congregate and feed undisturbed. Waterfowl feeding in surrounding small grain fields were induced into the lure crop and allowed to feed until the damage potential passed. This process increased feeding efficiency and reduced trampling.

In 1975 and 1978 the project was funded at the $300,000 level. The 1976, 1977, 1979 and 1980 projects had an operational budget of $125,000 to $150,000. From 1975 to 1978 complete expenditures of annual funds did not occur for the following reasons: (1) populations of mallards and pintails, the species which are responsible for most depredations, were low in some counties during harvest; (2) heavy rains in southern Canada delayed harvest and slowed migration into North Dakota; (3) refuge feeding programs kept ducks from entering fields outside the refuge boundary; (4) warm, dry weather allowed for an early harvest; (5) landowners were unwilling to sell a crop to FWS; and (6) an increase of straight combining and grain dryers reduced the length of time the grain was susceptible to waterfowl damage.

During 1979 and 1980 a combination of late spring planting and fall rains produced severe depredations which resulted in numerous opportunities for lure crop purchases and data collection.

METHODS

Lure Crop Purchase

Beginning in early August ground and aerial surveys were conducted to monitor the build-up in local waterfowl populations. Field observations were initiated after a concentration of several hundred field-feeding ducks were located or a complaint received. Data were gathered on numbers and species of birds in the area, length of time birds had been feeding in the field, distance birds were coming to feed, harvest and weather conditions, and land ownership. After contacting the landowner, the options of purchasing the grain as a lure crop field[4] or providing extension services for scaring the ducks were discussed.

Animal Damage Control (ADC) personnel had the responsibility for purchasing and releasing lure crop fields and personnel of the Agricultural Stabilization and Conservation Service (ASCS) appraised the selected field for yield and acreage. The value of the crop was determined by the current inbound elevator price minus the shipping charges. During the 1979 grain handlers' strike, lure crop contracts were based on Minneapolis or Duluth prices rather than the suppressed prices at local elevators. The contract was then completed and the area posted as a "LURE CROP". Adjacent landowners were advised how to scare birds from their unharvested fields into the lure crop.

The lure crop was released when harvest operations in the surrounding area were 75-80 percent complete and the weather conditions became favorable for resuming harvest. All lure crops were released and scaring devices placed in the field prior to the opening of waterfowl hunting season. This procedure prevented a large kill on opening day and allowed hunting by local sportsmen to resolve, by scaring, any later complaints which arose. Upon release of the field, observations were made on the amount and condition of the remaining grain. If mechanically possible, the landowner was required to harvest the lure crop. Salvaged grain was sold at a local elevator, the amount received deducted from the original contract price, and the difference paid to the farmer. If the field was not harvestable, $5 per acre was deducted from the contract price in lieu of normal harvesting costs. Some salvaged grain was of feed grade quality and was not accepted at the local elevator. In these cases, FWS stored this grain on a nearby National Wildlife Refuge for wildlife feed and the farmer received the full contract price.

In 1979 two harvested fields were rented and baited. Grain was trucked into the field, spread into windrows, and decoys added to attract ducks. Under a special contract, the landowner received a fee of between $250-$350, depending on field size, for the use of his field. Baited fields were released ten days prior to the opening of hunting season in compliance with federal hunting regulations.

Evaluation Procedures

Characteristics of lure crop fields and daily observations were recorded on two separate data sheets. The lure crop data sheet was completed at the time of purchase and daily observation forms were completed each time the field was visited.

During 1979 and 1980, 30 lure crops were selected for evaluation based on the following criteria: (1) expected to hold a minimum of 2,000 ducks; (2) available for sampling before more than two days damage occurred; (3) regular shape and uniformity with respect to yield; and (4) subject to daily observation without disturbing the feeding ducks.

Upon release, lure crops purchased in 1979 were divided into damaged and undamaged strata based on field observations. In fields where

[4] For the purpose of this report, the term "lure crop field" implies ownership of grain only, not ownership of land.

damage was 100 percent, no stratification was possible. Within each stratum, grain kernels from 20 six-inch-square samples were collected. In 1980, samples were also taken at the time of purchase and only ten samples were collected from each stratum or from the total field. These samples were used to determine the extent of damage caused by ducks feeding in a lure crop field.

RESULTS

Total costs of the North Dakota lure crop pilot project incurred from 1975-1980 totaled $289,493.95 (Table 1). Relatively dry weather conditions during the years 1975-1978 resulted in the purchase of one lure crop in 1976 and six in 1978. Late spring planting and fall rain, however, resulted in severe depredations and the purchase of 34 lure crops in 1979 and 21 in 1980. Between 1976 and 1980, 16 barley, 24 spring wheat and 20 durum crops were purchased (Table 2). During 1979, two harvested fields were rented and baited (Table 3).

The 1979 and 1980 evaluation was designed to measure the amount of damage caused by ducks feeding in a lure crop, quantify trampling damage, and calculate a benefit/cost ratio. In the lure crops used for this evaluation, damage caused by feeding ducks ranged from 2-100 percent in barley fields, 43-100 percent in wheat fields and 52-100 percent in durum fields. In 47 percent of evaluated fields grain damage was 100 percent because ducks ate and trampled all available grain, making harvest mechanically impossible. All of this damage was attributable to ducks because weather conditions cleared and adjacent fields were harvested.

Table 1. Summary of North Dakota Lure Crop Expenditures from 1975 to 1980

Year	No. of Lure Crops Purchased	Acres	Net Cost of Lure Crops	Administrative Costs	Evaluation Costs	Total Expenditures
1975	0	0	0	0	**$30,000.00	$30,000.00
1976	1	35	$5,502.50	*	**	5,502.50
1977	0	0	0	0	**	0
1978	6	180	19,157.52	*	0	19,157.52
1979	34	1,020	90,542.21	$28,519.00	0	119,061.21
1980	21	778	86,058.22	24,714.50	5,000.00	115,772.72
Totals	62	2,013	$201,260.45	$53,233.50	$35,000.00	$289,493.95
Averages	10	336	$33,543.41	$8,872.25	$5,833.33	$48,248.99

*Administrative costs of $8,100 in 1976 and $14,500 in 1978 were taken from operational Animal Damage Control funds.
**The 1975 $30,000 appropriation was spent between September 1975 and May 1977.

Table 2. Summary of North Dakota Lure Crops Purchased from 1975 to 1980

	No. of Fields	Size (Acres)	Yield (Bu/Acre)	Cost/Bu	Total Payment	Reductions	Net Payment
Barley							
Total	16	576.0	688.9	$40.19	$56,020.18	$9,502.10	$46,518.08
Average		36.0	43.1	2.51	3,501.26	593.88	2,907.38
Spring Wheat							
Total	24	629.37	836.42	92.00	87,519.40	5,111.97	82,407.43
Average		26.22	34.85	3.83	3,646.64	213.00	3,433.64
Durum							
Total	20	572.8	682.8	89.19	80,127.62	8,392.68	71,734.94
Average		28.6	34.1	4.46	4,006.38	419.63	3,586.75

Table 3. Summary of 1979 North Dakota Baited Fields

County	Size (Acres)	Cost	Grain Deposited (Bu)
Benson	50	$250.00	400
Burke	185	350.00	80
Total	235	$600.00	480
Average	118	$300.00	240

The damage factor used to quantify trampling losses was defined as the total damage, which included trampling and eating, caused by ducks, divided by the amount of grain eaten by ducks. Thus the damage factor is $D = \frac{T\&E}{E}$ where T=amount of grain lost to harvest by trampling and E= amount of grain eaten.

Studies conducted by Hammond (1961), Sugden and Georzen (1979) and observations from the 1979 lure crop project were used to estimate damage factors in the following example. Based on a consumption rate of 115g/bird/day (Sugden 1979), an average 1979 lure crop yield of 35 bu/a and life of 30 days, and the observation that birds were scared from unharvested fields about every two days (Duncan and Zahn, pers. comm.), the following conclusions were drawn: For field sizes of 10-50 acres and flock sizes of 100-10,000 birds, damage factors would range from 2.5-3.15 for barley. In fields with 1,000 ducks, which is the average number in a lure crop field at the time of purchase, the damage factor would be 3. This means that if a lure crop had not been purchased in this area, the dollar value of damage to small grain would have been three times as great as the purchase cost.

Data on the amount of total damage caused by ducks were used to calculate the benefit/cost ratio. Costs were defined as the amount of funds expended on personnel, logistics, equipment, administration and field purchases. Benefits were defined as the dollar value of total damage ducks would have caused without a lure crop field. By dividing the total losses due to depredations (92,027.05) by the net cost of the fields plus administrative costs ($137,654.38) and multiplying by a damage factor of 3, a benefit/cost ratio of 2:1 was calculated for the North Dakota lure crop pilot project.

The number of complaints a lure crop field prevented were estimated by two methods. First, 62 complaints produced the purchase of 60 lure crops and two baited fields. The depredating flocks associated with these lure crops produced an additional 85 complaints before the fields could be purchased. Therefore, a total of 147 complaints were actually resolved by lure crop purchases. Secondly, 30 complaints could have potentially been resolved by the purchase of each lure crop field. This estimate is based on data which indicated that in 77 percent of the reported complaints, ducks were allowed to feed in a field for two days or less. These data are substantiated by the following field observations. In the Mud Lake area during 1979, five complaints were received concerning the same flock of birds over a ten-day period. On the 11th day a lure crop field was acquired and complaints ceased. During 1978 in the Kulm area, approximately 80 complaints were received involving four flocks of ducks in a 20-day period. In some cases, ducks had only alighted in a field before being frightened while in other cases ducks were in the field one to two days (Duncan and Zahn, pers. comm.).

Based on a 60-day damage season and the observation that ducks generally are not allowed to spend more than two days in a field before being frightened, a depredating flock could damage 30 fields. Therefore, a minimum of 147 and a maximum of 1,860 complaints were resolved by the purchase of 60 lure crops and the rental of two baited fields. These data indicated that the purchase of a lure crop stopped all waterfowl depredation complaints in the surrounding area.

Effective range of the lure crops extended to a maximum of five miles based on daily observations of the distance birds traveled from the roost to the field. However, the roost being utilized by ducks was located less than one mile from the field in 78 percent of the lure crops. In several cases, ducks switched roosts to a wetland less than a mile from the lure crop field. These observations indicated lure crops with adjacent wetlands were preferred. In one extreme case, a Nelson county lure crop field attracted, on a daily basis, a flock of ducks 16 miles from Stump Lake. The fidelity of ducks for a selected undisturbed feeding site was indicated by many observations of ducks flying over several miles of swathed grain fields to feed in a lure crop.

The number of days a lure crop was utilized by ducks ranged from 0-48. Fields with zero days usage resulted from preselection, by ADC personnel, of a lure crop field. Ducks appear to have their own criteria for feeding site selection and attempts to preselect alternative sites and attract ducks into those fields failed. Several reasons existed which explain the low number of days of utilization. First, some lure crop fields contained an insufficient food supply and a large number of ducks rapidly consumed all available grain. Second, numerous alternative feeding sites were available. Third, vehicular or human harassment disrupted the waterfowl feeding pattern. Fourth, fields purchased late in September could be utilized by ducks for only a short time before being released prior to the opening of waterfowl hunting season. However, ducks could be held for an entire 60-day damage season when allowed to select their own feeding sites and feed undisturbed, given that a large enough lure crop was purchased.

Ducks will often select another swathed field as a feeding site after abandoning a lure crop. This presented two management options. The first was to purchase a replacement lure crop near the original, which produced very limited results. Ducks often required two to three days to select another permanent feeding site and in the process damaged numerous surrounding fields. The second option involved hauling supplemental grain into the original field. This method could not be used in years when fall rains prevented vehicle access to the field.

The percentages of standing, swathed and harvested fields were determined within a three-mile radius of all lure crops purchased from

1976-1980. These data revealed that lure crops were purchased when harvest was 0-85 percent complete. These data were based on small grain only; row crops, such as sunflowers, were excluded. An examination of the relationship between harvest conditions and lure crop effectiveness indicated that all lure crops purchased after the harvest was 50 percent complete could not effectively hold ducks due to the abundance of alternative feeding sites.

The percentage of fall-plowed fields within a three-mile radius of all lure crops was recorded. This revealed that in 88 percent of the lure crops purchased, less than 25 percent of the surrounding fields had been tilled. Fall plowing is defined in this study to be any agricultural practice which results in all available grain being removed. Harvested fields which were tilled once were classified as "harvested fields" because available grain remained, allowing these fields to be used as alternative feeding sites. Fall plowing conditions at the time of purchase ranged from 0-30 percent completed and averaged 13 percent. In 1980, additional data collected from 13 lure crops revealed the amount of fall plowing averaged 10 percent at the time of purchase and 18 percent when lure crops were released. These data indicate that during the damage season, only an additional 8 percent of the surrounding fields were plowed. Data analysis revealed no statistical relationship between fall plowing and lure crop effectiveness.

Hills were a component of 55 percent of the lure crops and 65 percent of the 172 surrounding fields surveyed. Data analysis indicated lure crops did not have a higher probability of having a hill than any of the other surrounding fields. These data imply that hills were not a factor used by ducks when selecting a feeding site.

Grain consumption approached 100 percent in 34 percent of the lure crops. Statistically no relationship existed between the percentage of grain eaten and the effectiveness of a lure crop field. For example, one completely consumed lure crop was ineffective in preventing depredations because the birds abandoned the lure crop and damaged many of the surrounding swathed fields. Conversely, in one lure crop only a small percentage of grain was consumed before the field was released. However, that field was effective in preventing any further depredations in the surrounding area. Factors such as number of days a lure crop was utilized, population size, yield, size of field and alternative feeding sites determined the extent of grain consumption.

Population counts revealed 89 percent of the lure crops contained 2,500 birds or more at the time of purchase or shortly thereafter. In the remaining 11 percent of the fields, population levels were below 500 when purchased and never exceeded 2,500.

Size of lure crops ranged from 6-75 acres and averaged 30 acres. Based on bird use days, the optimum size of lure crops ranged from 18-42 acres. The number of days depredations were occurring before the purchase of a lure crop ranged from 0-14. In 93 percent of the lure crops, depredations were occurring eight days or less before purchase. Some of this delay was due to the logistics of completing the lure crop agreement.

The following conditions produced optimum results: (1) harvest operations in the surrounding area were 20 percent or less done, (2) at least 2,500 birds were present in field at time of purchase, (3) an adjacent roost, (4) field size between 20-45 acres, and (5) a sufficient amount of grain to hold birds but not an excess which would result in grain spoilage.

An extremely unusual situation developed in 1980 when an all-time record 30 inches of precipitation occurred during August and September, completely flooding most small grain fields in the northeast quarter of the state. Under these conditions, thousands of highly preferred alternative feeding sites became available and birds could not reliably be attracted and held on a lure crop. Furthermore, inundation results in grain quality deterioration and prevents mechanical access to the field for harvesting. Under these conditions there was no potential for grain harvest and purchase of additional lure crops could not be justified.

Comparative efficiency studies of lure crops versus baited fields were attempted in 1979 and 1980. In 1979, two harvested small grain fields were rented and baited. The first field successfully held 10,000 ducks for 12 days. The second field was rented when the harvest was approximately 60 percent complete and resulted in limited success because of an inability to hold ducks. The 1980 study was aborted because fall rains prevented vehicle access to the prearranged field. This example indicates that when wet conditions restrict access, feeding stations would have limited value in preventing depredations.

Mechanical scaring devices were not as effective as lure crops during the early part of the damage season. Most fields in the depredation area at this time contained either standing or swathed grain both of which are acceptable feeding sites for ducks, but neither are acceptable to the farmer. During the 1980 damage season, harvest in the Devils Lake area was only 40 percent complete when waterfowl hunting season opened. Therefore, during the entire damage season, in this area, alternative feeding sites into which ducks could be scared were practically nonexistent.

DISCUSSION

Analysis of field observations and data collected from the 62 lure crops revealed the following combination of factors produced successful lure crops: (1) resolution of all complaints within a 78.5 square-mile area, (2) lure crops of a sufficient size (50-100 acres) prevented

depredations throughout a 60-day damage season, (3) lure crops which were capable of supporting a minimum population of 2,500 birds were most successful, (4) lure crops purchased early in the damage season when the harvest was less than 50 percent complete were most successful, and (5) with a benefit/cost ratio of 2:1 lure crops proved cost effective.

Several problems were noted which reduced lure crop effectiveness: (1) when fall rains flooded fields or when the harvest reached 50 percent completion, numerous highly preferred feeding sites were created and ducks could not be reliably held in the lure crop; (2) in years with an extended damage season, small lure crops were quickly consumed allowing ducks to enter and damage surrounding fields; (3) lure crops which sustained a high percentage of damage at the time of purchase, were not able to hold birds for the duration of the damage season; (4) lure crops preselected before damage occurred failed because ducks could not reliably be forced into the field; and (5) lure crops which had a small population at the time of purchase did not exceed 2,500 birds during the damage season and were not cost effective. The following factors were investigated and subsequently shown to have no effect on lure crop efficiency: the number of days of use, grain consumption, presence of hills, and fall plowing.

Analysis of the factors contributing to a successful lure crop resulted in establishment of general and specific criteria. The general criteria for implementation of a lure crop project in a state were: (1) the presence of a bird species which can be scared from field to field easily, quickly, and can be prevented from returning; (2) the ability to attract birds to a lure crop and keep them from surrounding fields; (3) a large concentration of birds must exist in the depredation area; (4) crops must be vulnerable to depredations at the time bird concentrations build up; (5) the potential for a long damage season should exist; and (6) damage must be greater than that caused by eating.

Specific criteria established for lure crop purchase were: (1) a minimum of 2,500 ducks must be present in the surrounding area; (2) during a 30-day damage season, lure crops should be no more than 50 acres in size but a 60-day damage season may require the purchase of 100 acres; (3) the number of alternative feeding sites must be minimal; and (4) damage to the field at the time of purchase must be minimal, thereby creating the potential to hold ducks for the duration of the damage season.

This study indicated lure crops were uniquely suited to North Dakota for the following reasons: (1) lure crops were used only for ducks, geese, and cranes, species which were easily frightened and cause more damage by trampling than eating; (2) only small grain which was especially susceptible to rampling was used for lure crops; (3) when fall rains delayed harvest, acceptable alternative feeding sites into which birds could be scared were minimal; (4) the agricultural practice of swathing compounded trampling; and (5) the latitude of North Dakota is such that a delayed small grain harvest coincides with waterfowl migration.

Field observations delineated circumstances under which lure crop purchases should cease. First, a lure crop should not be purchased when weather conditions result in grain deterioration and prevent harvest. Second, when the harvest reaches 50 percent completion supplemental techniques become more effective. Third, lure crops should not be purchased within two weeks of the opening of waterfowl hunting season because creating large artificial concentrations of waterfowl is not desirable at that time.

Baited fields and mechanical scaring devices were ineffective in controlling waterfowl depredations early in the damage season for the following reasons: (1) fall rains prevented mechanical access, (2) numerous alternative feeding sites existed, and (3) preselection of waterfowl feeding sites was ineffective.

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Control of One Native Animal Species To Benefit Another Native Species[1]

John T. Lokemoen[2]

This paper expresses my feelings on the topic of controlling one native animal species (small carnivores) for the benefit of another native species (waterfowl). The relationship between the predator and prey has always been an interesting one. During much of man's experience with wildlife, predators were generally feared and persecuted. It was almost universally agreed that killing predators resulted in larger game populations, which man wanted for food or sport.

These basic beliefs were seriously challenged by several authors in the 1930's and 1940's. Errington studied bobwhite quail in Wisconsin and Iowa and devoted many years to muskrat research in Midwest marshes. Errington became a strong believer that game animal numbers were a reflection of habitat quality. Early in his career Errington (1934) concluded that predators only preyed on bobwhite quail that were surplus to the carrying capacity of the habitat. Errington (1942) pointed out that some birds renested, and that helped compensate for loss to predators. In later papers Errington noted that muskrats suffered severe mortality, but suggested that most of the animals that died would have died anyway because of population pressures or other reasons. Other authors believed the predation on nests was a biological safeguard because it extended the nesting season so all birds would not be killed by a catastrophic storm. Kalmbach (1937) theorized that if crows had not destroyed nests then something else would.

The primary thought that dominated Errington's papers was that predation is a natural force that affects prey but has little significance for prey populations. He advised against extreme attitudes on the subject of predator control on behalf of waterfowl. During this same period Edminster (1939), Bump et al. (1947), and Crissey and Darrow (1949) were studying ruffed grouse in the eastern United States. These biologists concluded that ruffed grouse egg success increased where predators were controlled, but the fall population of ruffed grouse did not increase. Crissey and Darrow (1949) saw a temporary increase in ruffed grouse numbers on Valcour Island where predators were moved, but a slump in the population occurred when disease occurred two years later. About this same time other authors were pointing out that bounty payments on predators resulted in few increases to game numbers.

In total, the above-named authors had an important influence on the theory regarding predation. The papers published by these people produced a philosophy dominant in the 1950's and 1960's that controlling predators was ineffective in benefitting game populations. Game populations were thought to be primarily affected by habitat. The attitudes generated by the studies of the 1930's and 1940's probably reached a peak in the early 1970's when the Leopold (1964) and Cain et al. (1972) reports were issued. These reports examined predator and rodent control programs of the U.S. Department of Interior and resulted in bans on techniques for controlling predators such as the use of strychnine poisons. In most of the areas of the United States habitat management became the primary practice of the game manager. Predator control was seldom used. It seemed that only the first tenet of the Leopold report, which stated "all native animals are resources of inherent interest and should be cared for," was remembered. The second tenet, which said that local population control is an essential part of management where species cause significant damage to other resources, crops, or human health or safety, was forgotten.

Habitat management is indeed a primary tool of the game manager. If managers could dictate the pattern of food, cover, and water in the Dakotas, the resulting ecosystem would be naturally productive of wildlife, and there would be less concern for other management options such as predator control, disease control, bag limits, or shooting hour limits. However, this is not a viable option, and management practices have to be primarily applied intensively on the few acres of land that wildlife people control.

In the eastern Dakotas management of waterfowl by wetland protection alone has not been effective in increasing duck populations. Where wetlands exist Cowardin and Johnson (1979) estimated that the mallard population on unmanaged areas was decreasing at a rate of 2% yearly. In a managed situation with wetland and planted nesting cover, the population of mallards was increasing about 12% annually. Where there was a combination of wetlands, planted cover, and predator control, the mallard population increased at a rate of 263% annually. In eastern North Dakota, Johnson and Sargeant (1977) calculated that 10 to 20% of the mallard hen population was killed by red foxes each spring. This loss may be more mallards than are killed by hunters in the fall.

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[1]Talk presented at the 8th Great Plains Damage Control Workshop. (Rapid City, SD, April 28-30, 1987).

[2]John T. Lokemoen is Wildlife Biologist, Northern Prairie Wildlife Research Center, Jamestown, ND.

In any discussion of predator management as a tool, the following four major arguments are presented against the use of control: 1) Removing predators has little effect on reproductive success; and, even if reproductive success does increase, the population is held in check by other factors. 2) Reducing numbers of predators upsets the delicate natural balance. 3) Predators are necessary to remove the weak and diseased and thereby maintain healthy survivors. 4) If predators were removed small animals would increase abundantly.

In rebuttal to point 1), several studies have reported increases in game populations as a result of predator management. At Agassiz National Wildlife Refuge, Balser et al. (1968) found increased duck production on that part of the refuge where predators were removed. In California, Gladding et al. (1945) studied the Dunes Lake Club, where valley quail increased greatly when there was a reduction in grazing, increased feeding, and predator control. When predator control was stopped, the quail population slumped almost to zero. On a 100 square mile area in South Dakota where red fox, striped skunk, badgers, and raccoons were controlled, pheasant population averaged 132% higher. Population of ducks on that 10 square mile block rose from about 7 pairs of mallards per square mile to some 44 pairs of mallards per square mile. The population increase was probably a reflection of production one year, and homing of those hens and their young the next year.

In regard to Errington's comment that predators take only prey that is surplus to the population, Lack commented that all Errington's figures showed is that predators took more bobwhite quail when they were abundant than when they were scarce.

Point 2), the balance of nature concept, we often see perpetuated by popular magazines; scientists have called this idea a myth, with good reason. Ehrlich and Birch (1967) pointed out that even in natural situations animal populations undergo dynamic periodic, seasonal, and even daily changes. At a particular site one population may increase greatly or become extinct within a short period. In the Dakotas, for instance, the prairie chickens were introduced to the states as breeding birds, rose to high populations, and declined to near zero in the last 100 years. In this paper I was supposed to talk about the effect on natural predators. However, it is difficult to list the natural complement of predators because several, such as the red fox and raccoon, are new or much increased over pristine conditions. Several species, such as the grizzly bear and plains wolf, are gone, and new ones, including rats, cats, and dogs, have been added.

Point 3) states that the predators take the weak, injured, or diseased, but it might be more accurate to say predators take animals that are vulnerable. In the eastern Dakotas, the animals that are vulnerable are the hens that put nests in narrow shelterbelts, fence rows, and the like where red fox and striped skunk routinely patrol.

In conclusion, I believe it is reasonable to affect one population of animals negatively to benefit another. We live in a highly altered environment in which habitats and wildlife change daily. Wildlife managers must be allowed to manipulate all aspects of the environment if they are to have a strong impact on managed animal populations. If managers are limited in the management tools they can use, they will be severely limited in results achieved. When predator control is accomplished it should be done with the following constraints: 1) Predators should not be reduced on large areas that are natural and contain vegetation or animals that were there when man arrived. 2) There should not be any use of hit-or-miss bounty systems. I think we know that the bounty system as applied in the past is not effective in benefitting game populations. 3) Predators should not be controlled where an endangered species might be affected negatively.

Intensive management would have to be practiced on selected areas containing good habitat. Upland nesting waterfowl is an excellent group to manage because it responds well to intensive management. To increase waterfowl production, predator management used to take place only for a short time of the year, mid-March to early July. From previous studies only three animals were responsible for most of the upland nest losses--red fox, striped skunk, and raccoon--so we probably need to apply predator management to only these species. Predator management may have to be different from the forms it has taken in the past. Animals may have to be live-trapped and moved, excluded by fencing, or deterred by chemicals.

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Policy and Goals of the State of South Dakota[1]

Gay Simpson[2]

I am to address the policy of the Department of Game, Fish and Parks toward predator control and management in relation to waterfowl. Waterfowl has always had a high priority with the state of South Dakota. As a state agency, we could have said "let the Feds do it," but we did not take that approach (1) because South Dakota is a production state, lying where it does on the northern end of the Central Flyway, and (2) because we have a healthy population of waterfowl hunters. We sell about 40,000 duck stamps annually. The Department has recognized the importance of waterfowl to the state and its hunters and consequently has given waterfowl a higher priority than it might otherwise have had.

This priority for waterfowl in the state of South Dakota has recently been reinforced, primarily through participation in the Central Flyway. The Central Flyway Council adopted the Central Flyway Mallard Management Plan in July of 1984. By vote in Council, the state of South Dakota endorsed that plan. The plan's primary goal is to increase mallard recruitment. Clearly, the state has committed itself along these lines.

What are we doing and what is the policy? There is no Department-wide policy at this time. As a state agency we are somewhat committed to multiple species management, as is reflected on the lands we manage. They contain a variety of habitat manipulations that are not beneficial to waterfowl. A good example is the tree plantings undertaken in our pheasant restoration effort. We go out onto a native prairie and plant tree belts that may be very good winter cover for pheasants but are also handy dandy homes for some very effective duck predators. We are adding a new element to that part of the landscape, changing the odds for nesting ducks by providing habitat for new members of the community. Thus we have programs within the Department of Game, Fish and Parks that are nearly at cross-purposes with the fairly narrow goal of increasing waterfowl recruitment.

I was requested to write a five-year program plan when I was hired by the Department of Game, Fish and Parks. In that plan, I recommended the following approach to meet our objectives with waterfowl: Choose those game production areas (GPA's) where waterfowl production potential is extremely high and maximize (not merely optimize) duck production on those areas, while optimizing elsewhere. Predator exclusion or control would be one element in management to maximize waterfowl production. This approach would not have to be all-encompassing, and would allow continued multi-species management on many areas. To date the five-year plan has received no endorsement or implementation authority from the Department.

The approach of the state with regard to managing furbearers (predators) is through its hunters and trappers. I'm not certain what the past situation was in South Dakota, but I get the impression from Conservation Officers that it hasn't been very long since these "critters" were called varmints in the state, and attempts to manage them as furbearers have been recent. We currently have furbearer seasons that are not what you would expect if the aim were to increase duck nest success in general. We have greater expanses of nesting cover that allow the birds to disperse. West River, the fox, raccoon and badger seasons are open year-round. East River, where those predators are a problem, those seasons are not year-round. In fact, the fox season ends February 28, the raccoon and badger on March 31, just prior, of course, to the time when taking those animals from GPA's might be beneficial for hen survival and nest success. At present, because we do have strong recreational and economic interests in furbearers (trappers and predator hunters), the Department of Game, Fish and Parks has a "de facto" policy of not controlling predators on state lands in spring to increase duck nest success, except behind predator-exclusion fences and on Lake Albert Island. Of course, there aren't too many people who are going to be interested in trapping fox after the value of the fur decreases.

We at Game, Fish and Parks are clearly not on track with a cohesive policy from the Secretary or the Division Director toward controlling predators. Our ADC group program, which you heard quite a bit about yesterday, has a comprehensive approach, but it is one that is not integrated with the duck recruitment program within the state. So we have some progress to make. There are some connections yet to be made. While recreational trapping during prime fur seasons will do little to make our GPA's safer for nesting hens in spring, we can utilize our own Department's ADC expertise in applying predator control on selected GPA's where we have reason to believe it will be effective. Such an integrated approach will be absolutely necessary if South Dakota is to meet its objectives under the Central Flyway Mallard Management Plan.

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[1] Talk presented at the 8th Great Plains Damage Control Workshop. (Rapid City, SD, April 28-30, 1987).

[2] Gay Simpson is Waterfowl Biologist, South Dakota Game, Fish and Parks Department, Pierre, SD.

Policy and Goals on National Wildlife Refuges[1]

Len McDaniels[2]

The information that I am to present is the National Wildlife Refuge policy in regard to predator control. One of the goals of the National Wildlife Refuge System is to perpetuate the migratory bird resource. Since 1983 the policy of animal control on National Wildlife Refuges is to assess the effects of predation on breeding ducks; and, if predators are compromising waterfowl production, controls may be implemented. However, in reading the manual for policy on predator control, I found there are a lot of "hoops" to jump through before starting a predator control program.

Several alternatives of predator control need to be considered. These include: (1) Environmental manipulation, such as eliminating predator den sites, but, primarily manipulation through habitat management. According to the refuge manual, habitat must be adequate for migratory birds to meet the objectives established for a particular refuge. (2) Live trapping and transfer of predators. This requires a lot of effort and only transfers the problem elsewhere. (3) Public or recreational harvest of predators. This practice is conducted at the wrong time of the year to keep predators away from duck nests. I have noticed that recreational harvest of predators makes remaining predators more "trap-wise" requiring extra effort to control. (4) Non-lethal repellants. (5) Physical and mechanical barriers, i.e., electric fencing. (6) Lethal reduction by trapping and shooting. (7) Lethal reduction with chemicals. Toxicants are prohibited on all National Wildlife Refuges for bird and animal control. However, there are specific exceptions usually involving endangered species like the whooping crane or Aleutian goose. In the late sixties 1080 drop baits were dropped from an airplane to eliminate arctic foxes on several islands in Alaska to enhance production of Aleutian geese. During the 70's and early 80's, refuge people from Alaska attempted and in several instances did eliminate arctic foxes from islands without lethal chemicals. However, it was a very labor-intensive project. Yesterday we heard they are again using lethal chemicals to control the arctic fox to raise Aleutian geese.

Approved plans are required for all predator control alternatives with the exceptions of live trapping and transfer, use of physical barriers, and repellants. All approved predator control plans are required to meet NEPA guidelines. One must discuss the proposed alternative or mode of action as well as all alternatives. Lethal control of predators is to be conducted on a site-specific basis and not on a wide-range population reduction basis. Control efforts cannot be implemented without coordination with research and development, and local state conservation agency. This basically summarizes the manual policy on predator control on National Wildlife Refuges.

Since working at Valentine Refuge I have generated a few ideas of my own on predator control and migratory bird production. One can identify major predators and control those species; however, another predator species will attempt to replace them. I wonder just how many predator species are actually available to destroy duck nests. I also believe that ducks, for some peculiar reason, are subject to excessive predation as compared to upland nesting of sharptails and pheasants. We identified coyotes and bullsnakes as our major nest predators on Valentine Refuge. When we reduced coyotes, bullsnakes became the major predator, eating the duck eggs that coyotes were no longer eating. Controlling coyotes without controlling bullsnakes did not reduce overall predation on duck nests.

We have areas on the Valentine Refuge with high waterfowl nesting densities, and it is surprising how few or small the predators can be and still devastate hatching success. A den of weasels in an area of high nest density can greatly reduce nesting success. The problem with long-tailed weasels occurs in mid-June, about the time young weasles become active outside the den. Trapping weasels is not a problem as long as we know they are present. But, in most cases dense cover makes it almost impossible to detect them. By the time you discover you have a weasel problem and find them, it is generally too late to implement control measures--the damage has already been done.

It seems that nest destruction never stops; if it is not one predator then it is another. Considering present land use I am sure that in the future the only way to go is by intensive management; that is, if we are to get duck populations up to objective levels that are on the books today. The only way to achieve high duck populations under existing land usage is to attract high duck nesting densities and keep predators away from them.

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[1]Talk presented at the 8th Great Plains Damage Control Workshop. (Rapid City, SD, April 28-30, 1987).

[2]Len McDaniels is Refuge Manager, Valentine National Wildlife Refuge, Valentine, NE.

Policy and Goals of the U.S. Fish and Wildlife Service[1]

Harold Doty[2]

A recent memo out of our regional office says that we shall refer to this subject as seasonal predator management. You know it covers a lot of other terms; we used to call it predator control and so on. But going back to the origins of predator management in this country, we generally think of protecting domestic crops, be it trees or grains or sheep or cattle.

If you turn in another direction and look towards Europe, you can see many centuries of involvement in use of the land. There game is a product of the land and is owned by the landowner. They refer to game as their property and handle it as such. In some places it is managed out of existence, and in others it is highest on their agenda for production. Predators of game, if landowners want to raise game, are considered vermin. They are not given the time of day or words of praise. It gets down to standard approach and is not even talked about; landowners decided centuries ago that the vermin would be removed so that they could raise the pheasant or cottontail or whatever they want to raise.

I think back to the philosophy of the balance of nature, a popularized conundrum during the youth of most of us here and maybe at Northern Prairie Wildlife Research Center, where I worked from 1968 through 1984. In the early years (1960's) most of the people there had grown up with that philosophy and teachings, and it was rather a shock to see what was occurring with duck nesting out there in the real world. It was a significant shock to see the overall effects on nesting. By 1973 there was a consensus at that station that it was something that had to be reckoned with in one way or another if we were going to preserve or enhance waterfowl production. We have not come to the point of European game management, although that may be arriving on the East Coast and other areas east of here.

There are some more recent papers describing our written policies in the U.S. Fish and Wildlife Service. I am just going to read a few quotes from some of these. The one April 11, 1983 states, "It shall be the policy of the U.S. Fish and Wildlife Service to appraise the effects of predation on breeding waterfowl on service lands. In those circumstances, where it is determined that waterfowl production objectives are being compromised because of predation of waterfowl, their eggs or their young and other reasonable efforts have proven unsuccessful the service may implement predator management. This policy is to be implemented as a site specific application when definite results are desired not for the rangewide reduction of predator populations." The paper I gave yesterday is an early step into that realm of working not only on our lands but neighbors' lands. We have roughly two to three farms per square mile in that western Minnesota area. So we work with a lot of private landowners.

When appropriate, improvement of waterfowl nesting habitat is to be performed before the application of predator management and shall be continued during predator management activities. Jumping ahead to June 11, 1985, our previous director in Washington, Robert Jantzen, said that predator management "...should be used to increase waterfowl production on refuges and WPAs where predators are a problem." I took that out of context, but that was his statement and it still stands. Now there is another restriction. States must be consulted on assessments in predator/waterfowl relationships and should concur with any proposed management strategy on service lands. That has led us to the environmental assessments, and I have two draft copies here. One refers to this Midcontinent Project, another refers to the Wetlands Management Districts of western Minnesota. These are still draft copies and they are not accepted. They are getting heavier each time they are rewritten. They have been reviewed and comments have come in from such groups as the Humane Society of the United States. With comments both pro and con, both sides of the question are represented, I do not know how that will be resolved, yet. The Refuge Management Manual in June, 1985, states, "The policy of the U.S. Fish and Wildlife Service is to aggressively implement predator management in those circumstances where determination has been made that waterfowl production objectives are being compromised due to predation."

A recent waterfowl nesting study out of the Northern Prairie Center dealt with the Canadian prairies during the five-year standardized hunting regulations period on waterfowl, and also some extensive examinations of breeding habitat. Twenty-seven people, divided into five crews worked for three full years and covered a lot of prairies in Canada. Ray Greenwood out of the research center and Al Sargent rode herd over this project. The end result was that predation there is almost as bad as in North Dakota and western Minnesota. The old philosophy that our ducks all come out of Canada is not going to hold up. The headline of this news

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[1]Talk presented at the 8th Great Plains Damage Control Workshop. (Rapid City, SD, April 28-30, 1987).

[2]Harold Doty is a Wildlife Biologist, U.S. Fish and Wildlife Service, Fergus Falls, MN.

article says, "Ducks losing shrinking habitat areas to predators." So it is the same old story wherever we have looked. Here is another one that describes the data in Canada and the United States, and finds them comparable. The overall conclusion is that the odds are against the hens hatching a successful nest. The North American Waterfowl Management Plan came out in May 1986 and was slightly vague on this predator management thing; but, if you read carefully you can, on pages 25 and 26, come up with some specifics.

Referring to Fish and Wildlife Service or Dedicated Lands for Waterfowl Production, the Plan calls for improving duck recruitment on such lands. A variety of management techniques should be considered to reduce the effects of agricultural practices and predation on nesting ducks and their eggs. The desired result is to achieve a nest hatching success of 50% by 1995. Now, I checked into that and they are not talking about just observed or apparent nest success--they are talking about May field nest success. And, if that is a goal that is stated correctly, we are really going to have to confront predators on a wide scale or at least in some good habitat areas.

It has been determined that coyotes without young pups kill fewer sheep. So possibly a fox without pups kills fewer ducks. Al Sargent's data suggest that fox do not overkill. They will kill up to a ten-day supply of meat (keep it in the larder, so to speak) cached, and after that point they know where the ducks are nesting in their home range but do not necessarily kill them. This finding is based on research done nearly 20 years ago on Arrowwood Refuge in North Dakota. Other thoughts in predator management are aversion agents, which have gone through quite a lot of research without a lot of success; scent scramblers and aromatics which Ken Higgins has suggested from time to time; and other kinds of vegetation barriers, possibly. We have not found anything yet that keeps predators away from nests effectively for a very long period of time. Here is another thought--sound barriers. Maybe it holds something for the future; we do not know. Other kinds of research dealing with the biology of the species may be important; for example, removing litters from red foxes on home ranges and maintaining a pair there without young to feed. Habitat manipulations of other kinds are also suggested. There are probably other things that could be done in the way of intensive game management. I was looking at one of these brochures just yesterday on guard dogs. It may be a wild thought, but guard dogs may be trained to protect Waterfowl Production Areas. If we could find the right kind of dog with the right attitude and train it properly, then provided dog food, water and shelter, theoretically it could take care of the place. This would keep almost all of the predator management critics happy while enhancing waterfowl production. There could be other wild thoughts but that is just one of them. I am going to let it go at that point.

Policy and Goals in the Private Sector[1]

Rick Warhurst[2]

Today I am supposed to talk about policy and goals for predator management and control to enhance waterfowl production in the private sector. The private sector includes a wide array of interests. Each of you probably has a particular opinion. You have already observed some different thinking, some different languages, in reference to predator control from previous panel members. If you extrapolate that over the whole United States population, which would be the private sector, it would include a wide array of interests and thoughts.

In addition, there are a lot of different organizations, many wildlife conservation organizations. Obviously there are many different kinds of thinking, objectives, interests, etc., all having their own specific ideas on the subject. If you were to talk to John Grandy, of the United States Humane Society, you would probably get a different answer than I would give. Even though John did some work with waterfowl and knows waterfowl biology, his answer, I am sure, concerning control of predators to raise ducks would be much different than if you talked to Len McDaniels about the subject. I did not question some of the various other wildlife organizations, such as the National Wildlife Federation, Audubon Society, or the Sierra Club and others with which you are familiar, concerning their policy as it concerns predator control to enhance waterfowl production. I am not sure what their philosophies are completely. Maybe they do not have policies or philosophies or goals. However, I do not think they would be as enthused about controlling predators to raise ducks as some of us are about the subject.

Ducks Unlimited (D.U.) has a membership of 600,000, and all the habitat enhancement and development work that occurs, and all the money that is raised comes from those 600,000 people, which is a pretty small number when compared to the population of the whole United States. Our membership, which is primarily made up of duck hunters and people interested in seeing large numbers of ducks or waterfowl, has shown that they are willing to put their money up front so that they can enjoy the benefits of the sport of waterfowling and a wildlife legacy.

Of course, that is why back in 1937 when Ducks Unlimited was founded there were men with ample financial means and foresight enough to realize that unless something was done by the private sector, particularly in Canada, there was not going to be a waterfowl legacy. They had come through the severe drought of the 30's and had observed the skies that once were blackened with ducks dwindle to a scant remnant of ducks migrating up and down the flyways. These men could see there were not going to be any ducks in the future unless actions were taken quickly. Hence D.U. was established. So D.U. has put their money to work on the ground in the development of wetland habitats. Through the years D.U. has followed a singleness of purpose concept, the enhancement and development of habitat so that there would be production habitat for waterfowl. In recent years we have begun working on wintering areas and in most recent years, since 1985, working on migration habitat (MARSH Program). But still the main emphasis for Ducks Unlimited is in the waterfowl production country. Yesterday, in the paper I presented, I covered a wide array of projects, showing a lot of slides of some of the different kinds of projects we've built. We have used many different techniques and methods to separate predators from waterfowl nests, waterfowl nesting hens, and eggs.

Ducks Unlimited does not have a policy on predator control or predator management. We attempt to analyze a specific management area and to determine what is the limiting factor or factors for waterfowl production on that area; such as, a lack of secure nesting cover, or brood water, or a combination of these types of things. Then we address our project development to overcome that limiting factor so that waterfowl production can reach its maximum capacity or ultimate production potential on this particular management area. Again, our project attempts to address the factors limiting waterfowl production on the proposed project site. The development of proper habitat and the expansion of habitat has been the aspect which D.U. has stressed most during its fifty years. We have attempted to restore or create new or otherwise enhance waterfowl production habitat, particularly wetland habitat. Restoration of wetlands is an example of the types of production habitat improvement projects that D.U. develops. Yesterday I showed several slides of some of the twelve hundred acres D.U. has of wetland habitat restored in west-central Minnesota in cooperation with Midcontinent Waterfowl Management Program. That project also included restoring or reseeding 3,000 acres of upland nesting cover. Other D.U. projects involve installing water control structures

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[1] Talk presented at the 8th Great Plains Damage Control Workshop. (Rapid City, SD, April 28-30, 1987).

[2] Rick Warhurst is Regional Biologist, Ducks Unlimited, Bismarck, ND.

on various marshes which no longer produce as a result of a lack of water level control capability, severe infestation with rough fish, or if water levels have been too high in the area wetland too long. A planned drawdown of the wetland is utilized to restore high productivity and diversity to the marsh. We install control structures to facilitate drawdown of water and to allow more intensive management of the wetland.

Ducks Unlimited has developed projects in areas where there are fewer egg-eating predators or a different predator base, such as the West River country of the Dakotas and eastern Montana. Yesterday I mentioned some results concerning some of our brood counts on a few of the West River projects. They do produce ducks. These wetlands are not in what is considered prime prairie pothole country, but when water is available in the West River country, those wetlands do produce ducks. They produce ducks at an equal rate or better than some of the areas that we consider prime duck production pothole country.

We also create islands to separate predators from waterfowl nests either by separating peninsulas from the mainland with electric fences or physical excavations. We often build nesting islands. I showed a slide yesterday of a scraper sitting in the water at Katy's Lake in Montana after breaking through the ice, so building islands is not always nice and easy. It can be very expensive. Definitely electric fences are cheaper to construct; however, they do have a great deal of manpower maintenance requirements. For this reason we prefer, if it is possible, to cut off a peninsula to create a permanent island.

The use of artificial nesting structures is another method that we have tried to decrease waterfowl nest predation. You would think everyone would agree that nesting structures are a good idea, but that is not true. Within the U.S. Fish and Wildlife Service there are different philosophies concerning the use of artificial nesting structures. Some say they are not natural, they do not look good out there on the landscape. Ducks Unlimited is, I guess, trying to produce ducks, so within reason, we do not care how they look, if I can be so blunt. We want to produce ducks; we want to restore waterfowl populations to acceptable numbers--numbers with which sportsmen can be satisfied. and that are satisfactory to the general public. Gay Simpson mentioned to me this morning that some of the local folks up in Alaska in the Chugach National Forest region are not real happy with the idea of hazing brown bears away from the artificial goose nesting structures D.U. constructed and placed in the forest's wetlands to enhance production of the Dusky Canada Geese. Brown bears have become a major predaredator of the nesting geese. Nest success has fallen to very low levels. Hopefully the nest structures will provide predator-free nesting sites for the Duskys.

Again, the private sector includes a wide array of interests and a wide array of different thoughts and philosophies concerning predators. Just what is a predator? Some people would say a fox is just as important as a duck. It comes down to what our personal values are.

Hal Doty and Gay mentioned the North American Waterfowl Plan. It was signed May 1986, by the Prime Minister of Canada and our U.S. governmental officials. Ducks Unlimited is one of the first organizations to become involved with this and support the North American Waterfowl Management Plan. I mentioned yesterday that Ducks Unlimited has constructed some 3,200 development projects in Canada and in the U.S., including some 2,000,000 acres of wetland and waterfowl habitat that has been improved and enhanced for waterfowl production. One of the important aspects of this North American Plan is that it sets specific goals for different populations of waterfowl, and it also defines goals for habitat needs and habitat acquisitions.

Point number two of the specific Recommendations Section for Future Actions (p. 27) suggests that protection and improvement of over 1,000,000 additional acres of mallard and pintail breeding habitat in the pothole area of the north-central U.S. are also needed. That is a lot of acreage, especially in light of the fact, that for 50 years D.U. has been developing projects, and we have enhanced just a little over 2,000,000 acres. Over 1,000,000 more acres are needed. It's a big challenge. Ducks Unlimited has pledged over 550 million dollars over the next 15 years as a minimum for meeting these habitat needs. We have challenged some of the other wildlife organizations, to put it in the words of Dale Whitesell, our former executive vice president, "to put their money where their mouth is" so to speak--to get behind this Plan and to give their support monetarily to expand the habitat base for waterfowl and waterfowl production.

In summary, we do not have a policy and goal for predator management in Ducks Unlimited to control predators to enhance waterfowl production. We try to examine the limiting factor for waterfowl production on a proposed project site and address our project development to overcome this weakness to allow the specific management area to produce more waterfowl. If a lack of secure nesting habitat is the limiting factor, we address that by trying to develop electric fence cutoffs or electric fence exclosures, or constructing nesting islands to attempt to improve waterfowl production. The management of our projects within the United States is the responsibility of the cooperating agency. For example, if we develop a cooperative project with the South Dakota Department of Game, Fish and Parks, a Project Management Plan is submitted by the Game, Fish and Parks to us prior to D.U. contracting for development of the project. If we are both in agreement with the plan, the project is developed. The implementation of that plan is the responsibility of the Game and Fish Department. What about some of those predators out there on the islands and peninsulas that get trapped there after you get it fenced? Each year, just after ice out, the managing agency personnel clean off the islands or the various peninsulas. Ducks Unlimited does not have the personnel to do that. Again the cooperating agency

does the management. They remove predators from the islands and points.

I have tried to emphasize that in the private sector there are a lot of different interests and a wide array of philosophies. Some of the people may not agree with our D.U. philosophy. Six hundred thousand people who are members of Ducks Unlimited contribute very substantially, and would like to see more waterfowl. We are willing to do whatever it takes to insure that waterfowl legacy for my children, your children and future generations.

Decoying Coyotes with Dogs[1]

Gary J. Rowley[2] and DeLyle Rowley[3,4,]

Abstract.--Decoy dogs, used in conjunction with a predator call or coyote howl, are an effective technique to reduce coyote depredation on domestic sheep ranges during the spring and summer when coyotes are highly territorial and aggressively protect their young and den area. Trained decoy dogs, when chased by coyotes, return to their owner bringing the coyotes into shooting range. The type of dogs used successfully for this work is discussed.

INTRODUCTION

Professionals in Animal Damage Control (ADC) have used dogs (Canis familiaris) as a technique in controlling predation by coyotes (Canis latrans) for many years. Denning dogs are used in locating coyote dens (Wade 1978) and aid in destroying the pups; greyhounds hunt by sight, pursue, capture, and kill the coyote (Wade 1973), and hounds are used similar to greyhounds, but trail by scent (Duffey 1964, Hawthorne 1980). The use of decoy dogs in ADC operations started in the mid to late 1960's. Decoy dogs lure coyotes by provoking the defensive and den guarding behavior of coyotes by intruding in their territory and natal area.

Food and energy demands of adult coyotes steadily increase from estrus to weaning. Subsequently predation to livestock, particularly sheep and goats, also increases. Established territories and den sites are highly defended and protected (Kleiman and Brady 1978). Intruding canid species, particularly domestic dogs, are agressively attacked by coyotes in an effort to provide protection to their young. This display of defensive behavior is effectively used as a strategy to control depredating coyotes.

The use of decoy dogs in reducing coyote predation has many applications and can be successfully used in any habitat and terrain. It is one of the most effective and efficient means of selective coyote damage control during the late spring and summer grazing seasons.

APPLICATION

Adult coyotes normally hunt at night and early morning and return mid-morning to the den to feed their offspring (Young and Jackson 1951). Vocalization of adult coyotes is easily instigated at this time. Imitating a coyote howl by a person's voice or using a predator call encourages a response from the coyote(s). This response can be used for triangulation in estimating the coyote(s) location.

Approach the den site cautiously and select a "stand" location. It is very important to select a place where the wind is blowing directly from the den to the stand. This favorable wind direction provides an olfactory advantage to the decoy dogs in detecting the scent of the coyote(s) and a disadvantage to the

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[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop, Howard Johnson's, Rapid City, S.D. April 28-30, 1987

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[3]DeLyle Rowley, District Supervisor, USDA - APHIS - ADC, Montrose, Colorado.

[4]Gary J. Rowley and DeLyle Rowley are credited as forerunners instrumental in development, employment, and use of decoy dogs in operational ADC programs.

coyote(s) in detecting the shooter sitting on the stand. The use of 1 decoy dog has been successful, but 2 provide the best results. However, the use of 3 or more dogs appears to reduce success. It is speculated that the presence of 3 or more dogs may increase intimidation and decrease aggression in the coyote(s).

Once the stand is selected and the shooter is in position, reproduce a coyote howl. Usually, the coyote(s) respond with a return howl and come to investigate the sound. Immediately after hearing the coyote(s) howl, the decoy dogs respond and sprint toward the approaching coyote(s). After visually locating the coyote(s), the decoy dogs will begin to chase it. Coyote(s) will normally respond by barking as a warning to the encroaching decoy dogs. This barking also acts as a stimulus and encourages other coyotes near the area to investigate the disturbance. In some cases, the coyote(s) will become frightened when confronting the decoy dogs and retreat. However, frequently the retreating coyote(s) stops, holds its ground, reverses the dominance, and begins to chase the dogs. It is common for the decoy dogs and coyote(s) to exchange dominance during the chase. During this time, the shooter should be patient, restrict movement, and remain out of sight. With increased experience, decoy dogs learn not to chase coyote(s) for long distances before returning.

When the decoy dogs begin to return to the stand the coyote(s) will pursue, and their aggression and attacks intensify. Fights occasionally occur if the coyote(s) captures the dog. In very aggressive attacks, coyote(s) appear to be less cautious as full attention is given to the decoy dogs. This provides the shooter an advantage. When using decoy dogs from the start of denning season to late summer when the pups disperse, it is not unusual for more than 2 adult coyotes to appear and join in the chase. The authors have witnessed up to 6 adult coyotes attacking the decoy dogs in one location.

Most of the time when the decoy dogs return to the stand the coyote(s) will be following. Very often the decoy dogs will successfully lure the coyote(s) within 10 yards of the stand. The use of a shotgun accompanied with a rifle is recommended. Often the coyotes concentration on the decoy dog is so great that they pay no attention to the shooting. If escape occurs, encourage the decoy dogs to pursue and in conjunction reproduce a coyote howl. Occasionally the fleeing coyote(s) will stop, show aggression and resume chasing the decoy dogs and provide the shooter with another attempt.

Infrequently, the coyote(s) refuse to evoke a chase and will only respond to the decoy dogs for a short distance from the den site. A possible explanation for this behavior is that the coyote(s) are at their extreme distance from the den site. If this is suspected, select a closer stand, approach cautiously and prevent the coyote(s) from visually detecting the shooter.

BREEDS OF DOGS

No one breed of dog is specifically used in developing decoy dogs. It is the dog's individual characteristics, qualities and training which dictates the success. Usually medium sized dogs (25-50 pounds) with medium build are best suited. Color or physical appearance of dogs has little or no relative effect on coyotes. Short-haired dogs are preferred in summer due to the heat factor.

The more common breeds of dogs the authors have successfully used are: McNabb shepherds, Border collies, Australian shepherds, Norwegian elkhounds, and wirehaired terriers. A few of the hound breeds and large terriers have developed into excellent decoy dogs, but the majority tend to be too aggressive.

TRAINING

Preferred attributes and traits required of a dog for consideration as a prospective decoy dog are few. Proper training and experience are imperative in developing a successful dog. Basic characteristics needed in selecting a candidate dog are: (a) one that likes to hunt, (b) one that will free range within 400 to 500 yards, and (c) one that possesses a small amount of aggressiveness. Start the training by familiarizing the dog with a trapped or snared coyote to encourage assertiveness and build confidence. Have the dog accompany the trainer when calling and denning and allow the dog to free range. Accustom the dog with rifle and shotgun fire but avoid muzzleblast by restricting the shooting when the dog is very close

or directly in front. Once a dog becomes "gun shy", it is useless.

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Field Study—Steel Versus Lead in Aerial Hunting[1]

Duane Bernstein[2]
David Nelson[3]

The purpose of this study is to get an objective measure of the comparative performance of steel and lead when used in aerial hunting. Comparisons will be made by patterning lead and steel from 35 and 45 yards using improved cylinder and modified shotgun barrels. Tests will be conducted from the ground and air to compare penetration by lead and steel.

The use of steel shot in South Dakota's ADC aerial hunting operations was initiated primarily because of the availability of steel shot over the non-buffered lead shot. After steel shot was in use, three other positive characteristics began to show up in the favor of steel. These were pattern density, penetration and minimized recoil.

Pattern densities were evaluated in the field for 35 yards and 45 yards (see tables 1 and 2). The shot sizes evaluated are 4 buck, BB LL, BB steel, F steel and T steel. F steel is .220" diameter or slightly smaller than 4 buck, T steel is .200" diameter and BB is .180" diameter. The barrels used for testing were the 26" beretta A-302 I.C. for all shot sizes except the T shot. T shot was tested in the Browning Investor 26" with all chokes and the F shot in full choke. The 28" modified barrel was also a beretta A-302 3" magnum. A 40" circle was used instead of a 30" circle to better cover the silhouette of a coyote. The beretta A-302 I.C. 26" is used exclusively for aerial hunting operations in South Dakota. The pattern densities with this choke are very similar for BB LL and BB steel. The impressive characteristics of the BB LL and BB steel are the density of the patterns with 75 pellets and 90 pellets per load respectively. The F steel and 4 buck showed no consistency in patterns with each showing large holes in the pattern for all barrels tested. T steel shows promise with the I.C. barrel and a pellet count of 60 which helps to better cover a pattern as opposed to a 34 pellet count on 4 buck and 48 pellet count on F steel.

[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop (Howard Johnson's, Rapid City, South Dakota, April 28-30, 1987)

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Table 1--35 yard pattern density

Length	Barrel	Shot Size	40" Circle
26"	I.C.	1 1/4 BB Steel	94%
28"	Mod.	1 1/4 BB Steel	84%
26"	I.C.	1 1/2 BB LL	93%
28"	Mod.	1 1/2 BB LL	96%
26"	I.C.	1 1/2 4 Buck	76%
28"	Mod.	1 1/2 4 Buck	82%
26"	I.C.	1 1/4 F. Steel	92%
28"	Mod.	1 1/4 F. Steel	83%
26"	Full	1 1/4 F. Steel	98%

Table 2--45 yard pattern density

Length	Barrel	Shot Size	40" Circle
26"	I.C.	1 1/4 BB Steel	80%
28"	Mod.	1 1/4 BB Steel	86%
26"	I.C.	1 1/2 BB LL	77%
28"	Mod.	1 1/2 BB LL	87%
26"	I.C.	1 1/2 4 Buck	47%
28"	Mod.	1 1/2 4 Buck	68%
26"	I.C.	3" 1 1/4 F. Steel	81%
26"	Mod.	3" 1 1/4 F. steel	77%
28"	Mod.	3" 1 1/4 F. Steel	60%
26"	Full	3" 1 1/4 F. Steel	67%
26"	I.C.	3" 1 1/4 T. Steel	95%
26"	Mod.	3" 1 1/4 T. Steel	88%
26"	Full	3" 1 1/4 T. Steel	88%

Penetration evaluation was done at 35 yards and the number of pellets that exited the coyote on a broadside shot were counted (see table 3). With the operational use of BB LL and BB steel from the aircraft, penetration seems to be similar also.

Table 3.--Penetration of coyote at 35 yards

Shot Size	Number Through Coyote	Pellets Per Load
BB Steel	5	90
BB LL	7	75
F Steel	5	48
B Buck	0	34

The 1 1/4 oz. BB steel 2 3/4" load has a mild recoil which is also desirable to many aerial gunners. The 1 1/4 oz. 3" magnum F shot and T shot resemble the record of 1 1/2 oz. BB LL at least to our shoulder nerve endings.

Two concerns that have been voiced regarding the use of steel shot in aerial hunting operations are a super tight pattern and the time lag between the time a coyote dies on his feet and the time to which he realizes it and tips over.

The tight pattern is the result of a short shot string (see table 4). A 20 foot length of 48" brown wrapping paper was fastened to a fence and shot strings were measured at 60 mph. The BB steel does not string out like lead therefore it is essentially hitting the ground at the same time and showing a tight pattern on the ground below the airplane.

Table 4.--Shot String, 35 yards at 60 miles per hour.

1 1/4 BB Steel, 4 feet 1 inch, or 49 inches
1 1/2 BB LL, 5 feet 4 inches, or 64 inches
1 1/2 4 Buck, 5 feet 9 inches, or 69 inches
F Steel, 5 feet 6 inches, or 66 inches

Shot String was a +15" longer with BB LL than BB Steel. F Steel was a +17" longer than BB Steel. 4 Buck was a +20" longer than BB Steel.

As far as the time lag problem, BB steel again resembles BB LL in that it seems in order to gain good penetration we have to sacrifice knock-down power. If a coyote is centered in the "tight" and "dense" BB steel pattern at reasonable range, there is no time lag - he is done. If caught on the edge of the pattern, the coyote can be ventilated good enough for a lethal hit but will cover some ground before it tips over. If working in heavy cover or on more than one coyote, it is possible to lose valuable time working a coyote that tips over just as the next pass is being made or it tips over in heavy cover and is not spotted. Neither of these two concerns are really a problem to the aerial gunner that is adept in hitting a coyote with other shot loads because if he can center the coyote in the pattern the shot string isn't needed to help him hit the coyote and there are enough pellets on target so there will be no "lag time" to tip over.

This is not a scientific study but only a field evaluation of steel shot since we are already using it in our aerial hunting operation by our own choice.

Aerial Hunting Takes Sheep-Killing Coyotes in Western Montana[1]

Guy Connolly and Bart W. O'Gara[2]

Abstract.--This paper reports limited data to document that depredating coyotes were shot from a helicopter in western Montana in 1976. Coyotes marked themselves by puncturing diphacinone-filled collars on the necks of sheep they attacked. Subsequently, 11 coyotes were shot from a helicopter on 3 ranches where collared sheep had been attacked. Six coyotes contained diphacinone and thus were confirmed as having recently attacked or fed on collared sheep.

INTRODUCTION

The Federal-Cooperative Animal Damage Control program (hereafter called ADC program)[3] uses a variety of lethal methods to protect livestock from predators. During 1971-76 the ADC program in 13 western states killed 429,437 coyotes, of which 28.5% were shot from aircraft. Aerial hunting expanded significantly after the 1972 ban on predacidal uses of chemical toxicants (Executive Order 11643 and related EPA actions). The numbers of coyotes shot from aircraft increased from approximately 6,100 in Fiscal Year 1971 to 33,600 in FY 1976 (Evans and Pearson 1980; USDI 1979:29). The 1976 figure includes some 9,700 coyotes taken from fixed-wing airplanes, and 23,900 from helicopters. Since 1976, aerial hunting has continued to be important for protecting livestock, but rising costs of helicopter operation have led the program to rely more on fixed-wing planes and less on helicopters. In FY 1985 the ADC program in 15 western states took approximately 15,900 coyotes from fixed-wing aircraft and 13,400 from helicopters.[4]

The ADC program directs control as selectively as possible to the depredating individual or local depredating population (USDI 1979). However, there are few data to quantify the effectiveness of commonly used methods in taking particular individual coyotes that may be killing livestock at a particular place and time. This paper provides data to establish that aerial hunting on selected ranches in western Montana took coyotes known to have recently killed sheep, or fed on coyote-killed sheep, on these ranches. The data were produced in conjunction with studies of sheep neck collars containing diphacinone, a slow-acting toxicant that served as a chemical marker between time of dosing and time of death for coyotes that punctured collars during attacks on sheep.

METHODS

The toxic collar, or livestock protection collar, is a novel method to kill coyotes that prey on sheep and goats (fig. 1). When coyotes attack collared livestock and puncture the collars, they receive an oral dose of toxic liquid (McBride 1974). Several toxicants have been used experimentally. The present study with diphacinone collars has been reported in detail elsewhere (Connolly 1976, 1979; Connolly et al., 1976, 1978). It is summarized here to establish that the slow-acting toxicant served to mark coyotes that attacked or fed on collared sheep, so that these individuals could be identified later if taken by other control methods.

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[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop [Rapid City, SD, April 28-30, 1987].

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[3]The ADC program, formerly managed by the U.S. Department of Interior, Fish and Wildlife Service, was transferred on December 19, 1985 to the U.S. Department of Agriculture, Animal and Plant Health Inspection Service.

[4]Unpublished ADC program records.

Figure 1.--A 35-pound lamb with diphacinone-filled collar. Only 1 of the 2 collar packets is visible.

Diphacinone, 2-(diphenylacetyl)-1H-indene-1,3(2H)-dione, is an anticoagulant rodenticide used since the 1950s. It acts by blocking the formation of prothrombin in the liver by competitive inhibition of vitamin K. When formulated in propylene glycol and administered to nonfasted, captive coyotes with a syringe in a single oral dose to the back of the mouth, the LD_{50} with 95 percent confidence limits was 0.6 (0.3 to 1.2) mg/kg. Times to death ranged from 6 to 17 days for 16 captive or wild coyotes (Savarie et al., 1979).

Sheep neck collars made of polyvinylchloride were filled with 5% aqueous suspension of diphacinone (50 mg active ingredient/ml). This commercial formulation, "Suspension Vampiricida Difenadiona",was purchased from Motomco, Inc., Clark, NJ. Three different collar configurations were used. Each collar had either 2 or 4 toxicant packets of various sizes. Depending on the number and size of packets, each collar contained 50 to 200 ml of toxic liquid, or 2.5 to 10 grams of active ingredient.

Diphacinone collars were pen-tested by releasing captive coyotes into 1-hectare (2.5-acre) enclosures with collared sheep. Four collars containing 5% diphacinone were punctured by captive coyotes; all 4 coyotes died. Three other coyotes present in the pens during these tests also died after participating in attacks or feeding on dead, collared lambs. Four more coyotes died after they punctured collars containing lower concentrations of diphacinone. For all 11 coyotes that died in pen tests of diphacinone collars, times to death averaged 8 days (range 4-13 days). Each coyote exhibited normal behavior until 1-2 days before it died.

Body tissues from 11 coyotes dosed by collars and 13 other coyotes dosed by researchers were analyzed after death for diphacinone residues. All livers and most muscle samples contained measurable amounts of diphacinone (Connolly 1979; Savarie et al., 1979).

Following pen tests that showed diphacinone collars to be lethal to attacking coyotes, field tests were conducted on 14 western Montana ranches in 1976. The Eight Mile Ranch (O'Gara et al., 1983) near Florence, Montana was the main study area. Collared lambs were placed in fenced pastures where coyote predation had recently occurred or was expected. Average pasture size was 209 acres (n = 23 pastures, range 5 to 816 acres). The number of collared lambs per pasture varied from 1 to 29 but was usually 4 to 10. Some pastures also contained uncollared ewes or wethers, since larger groups of sheep seemed more attractive to coyotes. Adult sheep were not collared because coyotes usually selected lambs. While collared sheep were in the field, other sheep on each ranch were moved away or penned at night to protect them from coyotes.

Collared and uncollared sheep were checked daily for evidence of predation. Each dead or injured sheep was examined for characteristic wounds inflicted by predators and for other evidence relating to cause of death. Sheep carcasses were removed each morning.

Other methods of coyote control were used concurrently with collars on some ranches. The principal technique used by the ADC program was aerial hunting from a turbocharged Bell 47 helicopter. An ADC employee used a 12-gauge semiautomatic shotgun with BB shot to shoot all coyotes seen during flights over ranches where predation had occurred. Coyote carcasses were recovered so that liver and hip muscle samples could be preserved for diphacinone residue analysis. Sampling was limited to coyotes taken on or near ranches where collars had been punctured by coyotes within the previous 20 days. Based on recorded times to death, as reported earlier, it was assumed that all coyotes puncturing diphacinone collars would disappear from the population within 20 days. We also assumed that all coyotes puncturing collars would exhibit measurable diphacinone residues until they died.

In addition to coyotes taken by helicopter, 1 coyote was caught in a snare and another was shot from the ground. The latter animal was taken by a rancher near the carcass of a freshly killed, collared lamb.

Diphacinone in coyote tissues was analyzed by the methods of Bullard et al., (1976) as modified (Connolly et al., 1976). Presence of diphacinone was interpreted as evidence that the coyote was a depredating individual. Pen studies had shown that coyotes could be poisoned either by attacking collared lambs and puncturing collars or by scavenging contaminated lambs killed

Table 1.--Background data and diphacinone residues for 13 coyotes removed from ranches where sheep collars containing diphacinone were punctured by coyotes in 1976.

Number of collars punctured & Dates	Uncollared[1] sheep killed	Coyotes taken[2] Sample number	Date of death	Diphacinone (ppm) Liver	Hip Muscle
Eight Mile Ranch					
3 (3/24, 3/25, 3/25)	13	CR-C1[2]	est. 3/26	ND[3]	ND[3]
1 (5/8)	81	CR-C3	5/28	0.9	ND
		CR-C4	5/28	ND	ND
1 (5/29)	82	CR-C5	5/29	ND	ND
		CR-C6	5/29	2.3	ND
		CR-C7	5/29	ND	ND
1 (5/29)	64	CR-C8	6/1	ND	ND
		CR-C9	6/1	ND	ND
1 (5/29)	53	GEC 2, 3	6/13	7.3	0.7
DP ranch					
1 (9/24)	0	GEC 4, 5	9/28	1.3	2.6
		GEC 6, 7	9/28	1.9	1.6
GB ranch					
2 (9/29, 9/29)[4]	NR[5]	GEC 8, 9	10/3	1.4	0.9
RL ranch					
1 (9/5)	1	GEC 10, 11[2]	9/5	6.0	NS[6]

[1]Total for 20 days before coyote was taken.

[2]Coyote #CR-C1 was found in a snare on 4/3; estimated date of death was 3/24-3/28. GEC 10, 11 was shot by a rancher. Others were shot from ADC program helicopter.

[3]ND = not detected; less than 0.1 ppm.

[4]Three more collared lambs were missing and presumed killed. Collars were not available to check for punctures.

[5]NR = not recorded. Approximately 40 lambs were killed from late June to late September.

[6]NS = muscle not sampled. Stomach contained 114.2 ppm.

by other coyotes, but coyote-killed sheep rarely were scavenged on the Eight Mile Ranch. Of 105 carcasses left in the field and checked daily for feeding, only 4 instances of coyote feeding on 1-day-old carcasses were recorded (O'Gara et al., 1983). Prompt cleanup of collared lamb carcasses minimized their availability to scavenging coyotes and there was no other known source of diphacinone on the study areas. For these reasons, we think the diphacinone-positive coyotes recovered in this study dosed themselves by attacking rather than scavenging collared lambs.

RESULTS AND DISCUSSION

Thirteen coyotes were taken within 20 days after diphacinone collars had been punctured (Table 1). Six of 11 coyotes shot from a helicopter contained diphacinone and thereby were confirmed as having attacked or fed upon collared lambs in the previous 20 days. As described above, there is ample reason to regard the diphacinone-positive animals as depredating individuals.

All of the diphacinone-negative coyotes came from the Eight Mile Ranch where only a few

of the sheep killed by coyotes had collars (Table 1). Coyotes could have attacked many sheep on this ranch without encountering collared sheep, which were pastured separately from the main ranch flocks. In addition, helicopter collections were biased against animals that punctured collars because some of them would have died before aerial hunting took place. Coyotes may have been collected for 20 days after collars had been punctured, but the average time to death was undoubtedly much shorter. Therefore, the documented proportion of depredating individuals (6/11 or 55%) among coyotes taken by helicopter is regarded as a minimum estimate. The true proportion of sheep killers probably was higher.

The coyote taken by snare (CR-C1) was negative, but the animal shot near a freshly-killed collared lamb (GEC 10, 11) contained diphacinone. The concentration found in its stomach (114 ppm, Table 1) was the highest level ever recorded in our laboratory from a coyote. We speculate that this animal punctured the collar within 1 hour before it was shot.

Ranchers and ADC specialists ordinarily cannot identify depredating individual coyotes. Except on rare occasions when coyotes are observed and shot while attacking livestock, the removal of depredating individuals can only be inferred if predation stops after a particular coyote or group of coyotes has been taken. Such inferences are uncertain at best. The approach illustrated in this paper offers a more rigorous way to document the removal of depredating individuals.

The practical solution to coyote depredation is removal or exclusion of all coyotes from immediate localities where depredation is occurring or expected to occur. The limited results reported here support this concept, as they show that coyotes taken by helicopter near sheep flocks included individuals preying on those flocks.

As noted previously, these data were produced during efficacy tests of diphacinone sheep collars. If the study had been conducted specifically to measure the selectivity of aerial shooting for depredating individual coyotes, larger numbers of sheep would have been collared and the collars would have contained a nontoxic marker rather than a toxicant. The approach developed in this paper also could be used to study other methods of coyote removal, alone or in combination.

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Importance of Attractant Qualities for Improving a New Coyote Delivery System[1]

Steven M. Ebbert[2] and Daniel B. Fagre[3]

Abstract---Changes in effectiveness and nontarget species selectivity of a new system for delivering ingestible substances to coyotes (Canis latrans) were examined by systematically varying odor type and quantity used to attract coyotes to the device. The new delivery system's efficacy was comparable to the M-44 in our tests in south Texas. A synthetic lure improved the effectiveness of the delivery system when applied in amounts of 0.10 cc or 0.50 cc. Varying odor type did not increase the incidence of desirable coyote behavior, such as biting, but did increase rates of visitation.

INTRODUCTION

A new system for delivering certain types of ingestible substances to coyotes was developed recently based on studies of coyote behavioral responses to chemical odors. The Coyote Lure Operative Device (CLOD) was devised to take advantage of vigorous licking and chewing behaviors of coyotes responding to certain odors (Marsh et al. 1982). The intensity and duration of licking, biting, and pulling by captive coyotes increased when specific odors were applied to some bite-sized objects and combined with sweet tastes (Fagre et al. 1981).

The CLOD system (Marsh et al. 1982) is an integration of several components. A synthetic coyote attractant is applied to a sealed polyethylene bulb mounted over an acrylic stem and base. The CLOD is anchored to a metal stake driven into the ground. A sweetened syrup mixture, which can contain many types of active ingredients, is sealed inside the protective plastic bulb until the bulb is punctured. Coyotes are attracted to the CLOD by the synthetic attractant, and are exposed to the syrup mixture only after biting the bulb. The sweet taste of the syrup increases the likelihood of rapid consumption by coyotes. The CLOD is designed to prevent many nontarget species from being exposed to the syrup mixture. A hard stem inside the bulb is designed to prevent the CLOD from being crushed and/or broken open if trampled by ungulates.

This new delivery system for ingestible substances has potential as a coyote damage control method for toxicants or reproductive inhibitors, but also could deliver oral vaccines, biochemical markers, or combinations of these. If successful, the CLOD system may lead to greater flexibility in dealing with coyote damage problems.

Despite the potential of the CLOD system, there have been no comprehensive field tests involving high rates of coyote interaction with CLODs. South Texas has high coyote densities suitable for such field tests (Linhart and Knowlton 1975, Knowlton et al. 1986). As presently designed, the CLOD system depends upon odor stimuli to attract coyotes to the device and elicit specific behavioral

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responses. Odor type and intensity are known to be important for attracting coyotes to scent stations (Bullard et al. 1983) and could be important in eliciting specific behaviors. Coyote behavioral responses also may be a reflection of odor type (Bullard et al. 1983). The CLOD is effective only if specific behaviors (biting, pulling, licking) are elicited from coyotes. Development of the system was based upon specific responses to W-U lure by captive coyotes. As part of our efforts to evaluate and improve the new delivery system, we investigated the influence of odor intensity and type on the effectiveness and species selectivity of the CLOD, and compared the CLOD with another delivery device, the M-44.

STUDY AREAS

CLODs and M-44s were evaluated on several large properties in the Rio Grande Plains Region of southwest Texas. These properties had various coyote densities and previous intensities of predator control. In these tests, the rates of device visitation and types of behavioral responses directed to the devices were determined for coyotes and other animals by use of a modified scent station survey method (Turkowski et al. 1979).

MATERIALS

Delivery Systems

CLOD bulbs are low-density polyethylene 20-ml vials (R-vials[4], Tofunetics Co., San Jose, Calif.) used for storing biological samples and solutions (Marsh et al. 1982). These bulbs are filled with a 19:1 (by weight) corn syrup and powdered sugar mixture. The bulb mouths are trimmed to fit over stems with bases made of acrylic resin. The stems and bases, or cores, are drilled and tapped to screw onto bolts welded to 12 X 3/4-in angle-iron stakes. The stake is driven into the ground and anchors the CLOD.

M-44s are spring-loaded devices that forcibly eject sodium cyanide into or near a coyote's mouth when a baited capsule holder is pulled by the coyote. Ingestion of the cyanide is not deliberate. M-44s are widely used in Texas in efforts to control depredation by coyotes. The M-44 capsule holders were wrapped with 1 x 12-in red felt strips and boiled in paraffin. Plastic capsules containing sodium cyanide are usually inserted into these metal capsule holders, but in our tests, no cyanide capsules were used. Instead of capsules, rubber stoppers were inserted in the tops of the M-44s to prevent moisture and foreign matter from affecting ejector mechanisms.

Attractants

Four different attractants were tested: "W-U lure", "Mast's #6", "Carman's Canine Distant Call Lure" (CDCL), and "Abbreviated Synthetic Fermented Egg" (SFE DRC-6503). Three levels of the W-U lure were used in one test. CLODs and M-44s with no attractant were included in some tests to determine coyote and nontarget animal responses to device appearance.

W-U (Western Regional Research Center and the University of California-Davis) lure is a synthetic attractant that elicits biting and licking behavior from captive coyotes. The CLOD system was developed as a result of observing coyote responses to some chemical components of W-U lure. When applied to a bite-sized object and combined with a sweet taste, W-U lure has elicited vigorous biting and pulling from captive coyotes for as long as 10 min (Fagre et al. 1980). W-U lure is synthetic, so its constituents are known and remain constant between production batches. For these reasons, W-U lure was chosen as the standard attractant used with CLODs in our tests.

Mast's #6 is a commercially available fetid bait commonly used by animal damage control personnel in southwest Texas as a trap and M-44 attractant (Turkowski et al. 1979, 1983).

CDCL is a commercially available canid attractant. It has been evaluated as a coyote attractant in captive trials and in the field in several states. In an extensive study (Turkowski et al. 1979, 1983) in four states, CDCL was superior to 4 of the 6 other attractants tested. A similar unpublished study in Texas showed CDCL's superior ability to attract coyotes to scent stations[5].

Abbreviated SFE (DRC-6503) is a coyote attractant developed for the U.S. Fish and Wildlife Service West-wide coyote

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[4]Use of product names does not imply endorsement.

[5]Martin, David. J., and Daniel B. Fagre. 1986. Field evaluation of a synthetic coyote attractant. Texas Chapter of The Wildlife Society Annual Meetings [Kerrville, Tex., Apr. 3-5, 1986].

abundance survey; it is a synthetic alternative to the more variable Fermented Egg Product (Bullard et al. 1978). The excellent attractant qualities of abbreviated SFE are well-documented (Bullard et al. 1978, 1983; Turkowski et al. 1979, 1983).

METHODS

Stations consisting of a 3-ft-diameter circle of sifted earth were established every 1/3-mile on alternate sides of ranch roads. A single experimental treatment (device/lure combination) was placed within each smoothed circle. The assignment of treatments to stations was randomized within each group of treatments. All stations were examined each morning and signs of animal activity were recorded. Coyote responses to odors at scent stations have been described by Turkowski et al. (1979) and Bullard et al. (1978, 1983). The device was only replaced if bitten (CLOD), pulled (M-44), or disturbed in a manner that might affect subsequent visitation. CLOD deliveries were usually characterized by severely torn or punctured bulbs with little or no syrup remaining. It was assumed an M-44 delivery would have happened if the ejector was triggered and there was definite animal sign within the 3-foot circle. If replacement was necessary, the same device type was replaced at the station and the same type and quantity of attractant was applied. Tests lasted an average of 6 days.

Response rates to treatments were calculated two ways. Treatment visitation rates were derived by dividing the number treatment stations visited by each species by the total number of station nights for that treatment. A station night is 1 treatment at 1 station for 1 night. Rates of behavior (such as ingestion rates) were calculated using the number of ingestions presumed to have occurred for each species divided by the number of visits by that species.

The first 2 tests were designed to determine the CLOD's potential for delivering ingestible substances to free-ranging coyotes by comparing visitation and delivery rates of CLODs and M-44s. W-U lure and Mast's #6 were used on CLODs and M-44s on a 10,000-acre private wildlife ranch and a 15,000-acre State Wildlife Management Area (WMA). The private ranch had continuing efforts to control predator damage using M-44s, snares, steel traps, and by shooting from the air and ground. On the WMA, there was no attempt to control predator populations or hinder their movements. However, on this property a few coyotes were killed each year by hunters. CLODs and M-44s without attractant also were used as controls on these properties. A total of 102 stations was established at the private ranch and 72 stations at the WMA.

In the test of odor intensity, 4 levels of W-U lure were applied to CLODs at 108 scent stations on a 70,000-acre livestock ranch to determine the influence of lure amount on coyote visitation and ingestion rates. The lure was diluted with acetone to maintain the same liquid volume while changing only the amounts of W-U lure applied to the devices. Acetone was chosen as the diluent because it rapidly vaporizes and leaves little residue (less than 0.001%), which minimizes possible interaction with the W-U lure. The 4 lure levels were: no lure and 0.50 cc of acetone, 0.02 cc lure and 0.48 cc acetone, 0.10 cc of lure and 0.40 cc acetone, and 0.50 cc of lure with no acetone.

After the optimum quantity of W-U lure was determined, other attractants were evaluated with CLODs for their ability to elicit appropriate coyote behaviors. A test was designed to determine responses of coyotes and nontarget animals to 2 commercially available lures and a different synthetic lure. CDCL, Mast's #6, and abbreviated SFE were selected. In previous field tests[5], these 3 attractants were effective at drawing coyotes to survey scent stations and eliciting specific behavioral responses, such as biting and pulling. On each CLOD, 0.5 cc of attractant was applied.

RESULTS

Field Evaluation of CLODs

After 780 station nights at the first test site (the private ranch) with predator control, overall coyote visitation rate was 4% (35) and device activation rate was 1.5% (12) (table 1). Significantly ($P < 0.05$) more coyote visits were recorded for stations with devices treated with W-U lure than Mast's #6. No significant differences for rates of coyote visits or deliveries were observed between the CLOD and the M-44.

In contrast to the ranch with predator control, coyote visitation was 41% (160) on the second study site (the WMA) without predator control after 390 station nights (table 2). This visitation rate was 10 times greater than the rate at the ranch with predator control. Also, 100 incidents of CLOD or M-44 activations by coyotes occurred at the WMA. Devices treated with W-U lure received signifi-

Table 1.--Frequency of coyote visits and deliveries to coyotes by treatments after 780 station nights at the ranch with predator control[1].

ATTRACTANT	VISITS			DELIVERIES		
	CLOD	M-44	Total	CLOD	M-44	Total
W-U Lure	7	10	17	4	4	8
Mast's #6	9	4	13	0	3	3
Control	1	4	5	0	1	1
	--	--	--	--	--	--
Total	17	18	35	4	8	12

[1]Each device/attractant combination had 130 replications.

Table 2.---Frequency of coyote visits and deliveries to coyotes by treatments after 390 station nights at the WMA without predator control[1].

ATTRACTANT	VISITS			DELIVERIES		
	CLOD	M-44	Total	CLOD	M-44	Total
W-U Lure	33	35	68	24	26	50
Mast's #6	27	24	51	21	15	36
Control	28	13	41	12	2	14
	--	--	---	--	--	---
Total	88	72	160	57	43	100

[1]Each device/attractant combination had 65 replications.

cantly ($P < 0.05$) more visits and resulted in more deliveries to coyotes than controls or devices treated with Mast's #6. Although there were no significant differences, more coyote visits and deliveries to coyotes were recorded by CLODs than M-44s.

Coyote responses to CLODs often appeared vigorous. Frequently, bulbs were pulled completely off the cores and pieces of the plastic component were found several yards from stations. Occasionally, stakes were pulled up several inches or completely removed from stations. Other coyote activities directed at the devices, such as rubbing and rolling, digging, defecating and urinating were indicated frequently more at CLODs than M-44s.

Odor Intensity Test

After 520 station nights, the number of stations receiving coyote visits was approximately equal for CLODs treated with 0.10 cc (13%) and 0.50 cc (12%) of W-U lure. Coyote visitation was slightly more for the 0.10 cc treatment during the first and second exposure nights, but the 0.50 cc level elicited more biting and chewing by coyotes. Coyote visitation rate was equal (4% each) for 0.02 cc treatments and controls.

Stations with the 0.10 cc and 0.50 cc levels received significantly ($P < 0.05$) more coyote visits than the 0.02 cc level and controls. However, the coyote ingestion rates were not significantly different for the two groups. It was decided to continue to apply 0.50 cc of W-U lure and other attractants to CLODs and M-44s in future tests.

Odor Type Test

CDCL and W-U lure were more attractive and resulted in a greater number of deliveries to coyotes than did Mast's #6 and abbreviated SFE (table 3). CDCL did as well as W-U lure at attracting coyotes to stations and was equally effective at eliciting coyote behaviors neces-

Table 3.---Frequency of coyote visits and deliveries to coyotes by treatments after 400 station nights at the WMA[1].

LURE	VISITS	DELIVERIES
CDCL	31	13
W-U	24	10
Mast's	16	7
SFE	10	4
	--	--
Total	81	34

[1]Each device/attractant combination had 100 replications.

sary for deliveries of the syrup mixture within the CLOD (table 3). No qualitative differences were noted for coyote behaviors elicited by these 2 attractants. However, CLODs treated with CDCL were visited by a greater variety of animals than were CLODs treated with W-U lure. Additionally, 3 deliveries to raccoons (Procyon lotor) were recorded at CDCL treated CLODs but no deliveries to raccoons were indicated for W-U lure treated CLODs during the same test.

DISCUSSION

CLODs have significant potential as a new delivery system because syrup mixture doses were effectively delivered to coyotes in these tests. Data indicated CLODs worked as well on the ranch (table 1) and better on the WMA than the M-44s (table 2). Therefore, CLODs are not inherently aversive to coyote populations, even those targeted by control programs. Because effectiveness and selectivity of CLODs werecomparatively better than for the M-44 device, the CLOD merits further attention and development.

The W-U lure proved to be a highly effective coyote attractant when used with M-44s and CLODs. More deliveries occurred with W-U lure than Mast's #6 because it attracted more coyotes to scent stations and elicited essential responses. Ratios of ingestions to visits for either device were similar for each odor. Additionally, the W-U lure appears to be more selective for coyotes since there were fewer nontarget wildlife visits to, and deliveries by, devices treated with W-U lure.

Coyote visitation rates differed greatly between the ranch with a predator control program and the WMA, possibly because of a lower coyote density and/or because coyotes on the ranch were inhibited from approaching the devices or attractants. In either case, when coyotes visited stations, the probability of them puncturing CLODs and ingesting the contents were similar to those on the WMA, the area not subject to predator control.

The effectiveness of W-U lure when used with a CLOD was greatest at the 0.50 cc level, not only because it was most effective in attracting coyotes to stations over a 5-day period, but also because it had a greater probability of ingestion. However, the 0.10 cc level of W-U lure was effective for a few days. Lesser amounts were ineffective. In other tests[5] 1.0 cc seemed repellent to some coyotes and visitation rates increased over several days as the lure dissipated. Bullard et al. (1982) concluded that odor quantity influenced a synthetic lure's attractiveness, and Turkowski et al. (1983) also found that abbreviated SFE was more effective at lower levels.

Apparently, both odor intensity and type are important attributes for attracting coyotes to devices, but in our tests, did not affect the probability of inducing deliveries to coyotes during visits. This is reaffirmed by the odor type test. If the lure was highly attractive, it worked well with the CLOD. One synthetic attractant (W-U) was more effective than another (SFE). One fermented trap attractant (CDCL) was more effective than another (Mast's #6). Although rates of coyote visitation and ingestion were similar for CDCL and W-U lure, species selectivity differed. The CDCL attracted more nontarget wildlife, which is undesirable both from the standpoint of potentially affecting other wildlife and reducing the CLOD's delivery rate to coyotes. At this time, W-U lure appears to be an excellent choice to use with the CLOD system in south Texas.

The CLOD system has many possible advantages over the M-44 device. CLODs have no moving parts and do not rely upon precise manufacturing to function properly. Unlike with leg-hold traps or M-44 devices, the angle iron stakes may be driven into hard ground, soft mud or sand to securely anchor the CLOD without risking malfunction of the device. The CLOD system's simplicity may make it more reliable.

Because CLODs need directed, specific, and persistent behavioral responses from coyotes to deliver active ingredients, other wildlife may be at less risk of exposure to the active ingredients. Generally, an upward pull on the M-44 capsule holder is necessary to trigger an M-44, whereas this type of distur-

bance alone would not be sufficient to activate a CLOD. The CLOD's bulb must be bitten hard enough to cause a puncture before the mixture is exposed. Incidental investigation of M-44s by other animals may have a higher probability of springing M-44s, resulting in nontarget deliveries or making devices inoperable when approached by coyotes.

The M-44 device depends upon a forcible delivery mechanism, which probably causes an aversion to the device or odor used if the coyote survives. The CLOD system, however, relies upon voluntary ingestion of the sweet syrup and so it can be used with substances needing multiple deliveries to be effective. Once punctured, the syrup in the CLOD insures ingestion by coyotes, but other wildlife, such as felids, may not respond as positively to very sweet tastes (Boudreau and White 1978).

Furthermore, the dosage of active ingredients inside CLODs may be calibrated so complete ingestion of the mixture is needed to achieve the desired effect. Several times in the field it was noted rodents and lagomorphs had successfully gnawed through the plastic bulb but apparently ingested very little of the contents. If the plastic-dipped device and synthetic odor is not perceived by animals as a potential food item, it generally may be less attractive to wildlife than other control methods.

Finally, the active ingredients are sealed inside a plastic bulb which minimizes external contamination. Undisturbed CLODs are easily removed from the field intact, and this facilitates retrieval of chemicals used in coyote control efforts.

SUMMARY

The CLOD system warrants further research development as an additional delivery system to use for coyote management. If odors can attract coyotes, the CLOD's design will encourage further interaction. Further improvements may be accomplished by varying the CLOD's physical aspects, such as size, shape, and structure.

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Field Evaluation of Olfactory Attractants and Strategies Used To Capture Depredating Coyotes[1]

George E. Graves[2] and Major L. Boddicker[3]

Abstract.--Forty-five experimental and commercial olfactory attractants (lures) were tested under field conditions over a 30-month period to evaluate attractiveness to coyotes, elicited behaviors, and responses with lethal and simulated lethal coyote capture devices. The top 7 lures evaluated in spring and summer test periods that produced the highest simulated coyote capture rates with trap rings, M-44 heads, and break-away snares were WU 15-20%, Sheep Liver Extract, and (Carman's) Canine Distance Call Lure; (Carman's) Final Touch, Rotten Meat Odor, and TMAD 10%; and Estrous Urine Fractions, respectively.

INTRODUCTION

Behavioral responses that experimental and commercial coyote and carnivore olfactory attractants (lures) elicit to coyotes have been conducted in controlled experiments using captive coyotes (Timm et al. 1975, 1977, 1978, Fagre et al. 1981a, 1981b, 1983, Kruse and Howard 1983, Scrivner et al. 1984, 1985, 1987). Skepticism as to the validity and application of these results to wild coyotes has been expressed by researchers and field personnel (Teranishi and Howard 1986). An extensive and quantifiable field evaluation of experimental lures with actual applications with leghold traps, M-44's, and cable snares was needed.

Turkowski et al. (1983) suggested several factors that could cause variation in predator responses to attractants. These factors included weather elements, ambient temperature, length of lure exposure, seasonal periods, and individual coyote behavior. The purpose of this project was to test some of these factors and develop a transportable, productive, and cost effective method of selective coyote control. The approach was to evaluate, by field tests, delivery materials and strategies, lure formulations, mechanisms and chemicals to increase the probability of capturing coyotes and other predators. The objective was to determine which lures increased the efficacy and selectivity of leghold traps, M-44 sodium cyanide (NaCN) ejectors, snares, and other control devices under field conditions.

STUDY AREA

Investigators (4) selected non-overlapping study sites that had viable coyote populations and a history of livestock/coyote interactions. Fall and winter data were collected on sites and elevations normally used as sheep (*Ovis aries*) wintering areas. The sites consisted primarily of short-grass prairies between elevations of 1364-1818 m with blue grama (*Bouteloua gracilis*) the dominant vegetation. Lower montane regions, primarily composed of cedar (*Juniperus* spp.), pine (*Pinus* spp.), and sagebrush (*Artemisia* spp.) vegetation from elevations of 1515-2576 m were also used. Spring and summer data were gathered from sites where sheep normally lambed and ranged during summer. Sites including short-grass prairies, lower montane, montane (mainly composed of *Pinus* spp.), subalpine (*Picea* and *Abies* spp.), and alpine areas of north-central and eastern Colorado were utilized.

METHODS

The study was conducted between 1 Nov. 1982 and 25 Aug. 1985. Data were collected on combinations of lures and capture devices during fall, winter, spring, and summer of each year. Each test period consisted of a minimum of 20 days of field applications within a season and a minimum of 30 treatment sites. A treatment site was

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[3] Major L. Boddicker, Ph.D., owner-operator of Rocky Mountain Wildlife Enterprises, LaPorte, Colo.

defined as the placement of 1 lure with 1 capture device type at 1 location. Treatment sites were inspected approximately every 2 days (weather permitting). Data were collected on standardized data sheets.

Coyote capture devices were categorized as lethal and simulated lethal. Lethal devices used in the fall and winter (FW) test periods included leghold traps, M-44 NaCN ejectors, and cable snares. Leghold traps (usually 2 per treatment site) were placed in the soil, anchored, and covered to mimic standard practice following Boddicker (1980) and Hawthorne (1980). A capture was recorded if an animal was caught and held or caught but escaped before investigator arrived. Tracks and hair were evaluated to determine the species of escaped animals. Procedures used with M-44 NaCN ejectors were those prescribed by Beasom (1974), Shult et al. (n.d.), and Boddicker (1979). A capture was recorded if the M-44 NaCN ejector head was pulled whether or not an animal was recovered. Sign, such as tracks and teeth indentations on the head, was used to confirm the species. M-44 ejectors and NaCN capsules used were manufactured by and purchased from the M-44 Safety Predator Control Company, Inc., Midland, Texas[4]. Commercial cable snares, made from 0.16-cm twisted steel cable, were placed in locations that camouflaged their presence and near coyote trails and travelways. Cable snares were set following procedures prescribed by DeZarn (1984). A capture was recorded if an animal was caught and held or caught and escaped before investigator arrived.

Simulated lethal devices were utilized in the spring and summer (SS) test periods to maintain maximum opportunity for coyote-device interactions. Simulated lethal devices used were trap rings, M-44 heads only, and break-away snares. Trap rings were made from 1.25-cm cross sections of 15.0-cm diameter plastic pipe and placed in the ground in the same manner as were leghold traps. A simulated capture was recorded if an animal stepped inside 1 or both rings. M-44 heads, wrapped in hemp, but without beeswax or paraffin, were staked 8 cm above the ground by 20-penny nails placed through the head area that normally contained the NaCN capsule. A capture was recorded if the head was pulled upwards 2.5 cm or more from set height; head pulled out of soil, chewed, and dropped; or if the head was removed from the site. Break-away snares designed by G. Stewart, consisted of a 30-cm loop of 0.04-cm braided steel wire with a copper clip replacing the base ferrule. Break-away snares were placed using the same procedures as cable snares. Captures were recorded when snares were broken by an animal.

A standardized volume of approximately 0.5 ml of each candidate lure was presented on a neutral material that varied with the device used. Lures evaluated with leghold traps and trap rings were placed directly on cotton q-tips, bleached bones, cow chips, grass tufts, animal fur, or feathers. Lures were placed upwind and directly behind the leghold traps or trap rings so an investigating animal would usually pass over the trap when exploring the lure. Removal of used delivery materials from the study site reduced contamination.

When used with cable and break-away snares, lure was presented in plastic vials elevated approximately 1.25 m from ground level. Vials were suspended by cotton string and attached to brush and other supports. Placement was intended to force animals to pass through the snare(s) in their attempt to investigate the lure. Lures were placed directly to the head of M-44 NaCN ejectors and M-44 heads.

Experimental lures (EL's) evaluated in the study (table 1) were those developed by R. Teranishi, USDA, Research Leader Food Quality, Western Regional Research Laboratory, ARS, Albany, Calif., and associates. Trimethylammonium Decanoate (TMAD) and WU (a mixture of acids,

Table 1.--Experimental lures evaluated in the study.

Experimental olfactory attractants (lures)	Designation
Trimethylammonium Decanoate[1]	TMAD
Rotten Meat Odor[2]	RMO
Synthetic Calf Crap[3]	SCC
Synthetic Porcupine Hair[4]	SPH
Sheep Liver Extract[4]	SLE
Estrous Urine Fractions[4]	EUF
WU[5]	WU
WU Acids[4]	WU Acids

[1] Two formulations of TMAD were mixed by the principal investigator and evaluated. One part TMAD mixed with 99 parts pork lard (PL) to formulate TMAD 1%. One part TMAD mixed with 9 parts PL to formulate TMAD 10%.

[2] One part RMO mixed with 9 parts PL.

[3] Two formulations of SCC lure were tested. Equal portions of SCC mixed with liquid lanolin and designated as SCC (this formulation was mixed by R. Teranishi). The other formulation, designated as SCC + sugar, was mixed at a ratio of 4 parts SCC plus 1 part sugar.

[4] SPH, SLE, EUF, and WU Acids were used as received from R. Teranishi.

[5] Four formulations of WU were mixed by the principal investigator and evaluated. One part WU mixed with 99 parts PL to formulate WU 1%. One part WU mixed with 9 parts PL to formulate WU 10%. Four parts WU 10% mixed with 1 part sugar to formulate WU 10% + sugar. One part WU mixed with 5-7 parts PL to formulate WU 15-20%.

[4] Mention of manufacturer and trade names does not constitute endorsement by the U.S. Government.

sulfides, and trimethylamine) lures were diluted and formulated by M. Boddicker. Other EL's were used as received by R. Teranishi.

Fourteen commercial lures (CL's) (table 2) and 18 combinations of lures (Combos) were also evaluated. CL's were selected by M. Boddicker because of above average reputations as coyote attractors, or had been used in previous research conducted by Linhart et al. (1977), Turkowski et al. (1979, 1983), and Fagre et al (1983). CL's were used as received from the supplier. Combo lures resulted from the use of 2 or more EL's and/or CL's presented at 1 treatment site. In a Combo, lures were administered separately on delivery materials (usually q-tips) and placed within a 225 cm^2 area. Combo lures were only used with leghold traps and cable snares and predominately used in FW test periods.

Responding animals were classified as coyote, other carnivores, herbivores, and birds. Behaviors were categorized according to Turkowski et al. (1979). Investigators were trained to interpret behaviors exhibited by coyotes and other animals responding to the lures. Ambient temperature was taken between 7-8:00 a.m., recorded each day and at each study area, and assumed the low temperature for that day. Temperatures were grouped into range classes of 5 C each starting with -23.3 C and ending with 37.2 C. Barometric pressure was obtained from meteorological monitoring facilities located nearest to each study site and recorded as rising, falling, or stable. Lunar phases were recorded as either new or full. New moon was defined as the time duration beginning with the first day of the third quarter through the last day before the first quarter. Full moon duration comprised of the remaining time period not covered by new moon. Duration of lure presentation in days was recorded at each inspection. If reapplication of lure was necessary, duration was reset at 0 days and increased until a capture was made, lure reapplied, or site removed. Lure presentation or "lure age" was grouped into 2-day age classes.

Table 2.--Commercial lures evaluated in the study.

Commercial lure[1]	Designation
(Carman's) Canine Distance Call Lure	CDCL
(Carman's) Final Touch	CFT
(Carman's) Pro's Choice	PC
Olmstead Coyote Lure	OCL
Olmstead Bait	OB
Stokers Bounty	SB
Mast #6 (Coyote #6)	M#6
(O'Gorman) Gov't Call	OGC
(O'Gorman) Long Distance Call	OLDC
(O'Gorman) Wolfer Scent	OWS
(O'Gorman) Powder River Paste	PRP
Johnson's Bait	JB
Kents Coyote Butter	KCB
Fish Oil (Commercial)	FO

[1] Commercial lures were evaluated as received by the supplier.

The calculation of capture rate for each lure and variable was necessary to standardize the data. Capture rate for each lure was obtained by dividing the total number of coyotes captured by the total trapnights exposed (Turkowski et al. 1979). Analysis of variance (ANOV) was used to determine if significant differences exist between coyote and simulated coyote capture rates of variables for individual lures. Lures used in $\geq$5 test periods within a season and generating responses or captures of $\geq$5 coyotes in at least 1 test period were considered as having sufficient data for analysis. Bivariate linear regression was used for additional analysis of temperature data. The slope inclination of the plotted data provided the relative stability of the lure and the R^2 value provided the relative precision and fluctuation in capture rates.

RESULTS AND DISCUSSION

Investigators presented 44 lures at 2,328 treatment sites involving 46,164 trapnights. A total of 609 coyotes was captured in 15 FW test periods combining 25,478 trapnights. Leghold traps were used in 44.4% of total trapnights and captured 185 coyotes, M-44 NaCN ejectors composed of 48.7% of the total trapnights and resulted in 372 captured coyotes, and cable snares generated 6.9% of the total trapnights, capturing 52 coyotes. A total of 731 coyote-visits was recorded at simulated lethal capture devices from 15 SS test periods that generated 20,686 trapnights. Trap rings produced 64.5% of simulated coyote captures (N = 472) in 50.8% of total trapnights. M-44 heads were used in 45.3% of total trapnights and accounted for 33.5% of simulated coyote captures (N = 245), and break-away snares produced 1.9% of simulated coyote captures (N = 14) in 3.9% of total trapnights.

Devices

No one lure produced consistent FW coyote captures with all 3 lethal capture devices. Combos were effective in capturing coyotes when used with leghold traps, but not snares (table 3). CL's generated higher coyote capture rates than EL's when used with M-44 NaCN ejectors, but EL's produced higher coyote capture rates than CL's when used in conjunction with cable snares. Four lures, Synthetic Calf Crap (SCC), (Carman's) Canine Distance Call Lure (CDCL), WU 15-20%, and WU Acids (a mixture of C_2, C_4, C_5, C_9, and C_{10} acids) were analyzed using ANOV to determine if differences exist between coyote capture rates of lethal devices used. Coyote capture rates of

Table 3.--The top 12 lures evaluated in FW producing the highest coyote capture rates when used in conjunction with lethal capture devices. Lures used with capture devices generating <5 captured coyotes are not given.

Leghold traps			M-44 NaCN ejectors			Cable snares		
Lure	N coyotes captured	Capture rate	Lure	N coyotes captured	Capture rate	Lure	N coyotes captured	Capture rate
[1]CFT-C	11	0.093	OLDC	10	0.083	OCL	7	0.064
[2]Combo 5	20	0.048	CDCL	207	0.054	EUF	9	0.037
[3]Combo 6	6	0.044	OWS	13	0.054	WU 15-20%	8	0.031
[4]CDCL-C	25	0.037	SB	24	0.041	CDCL	17	0.026
[5]TMAD-CDCL-C	5	0.032	WU 15-20%	42	0.024			

[1] CFT-C consisted of Carman's Final Touch and coyote urine.
[2] Combo 5 consisted of SCC, CDCL, sugar, and coyote urine.
[3] Combo 6 consisted of RMO, CDCL, and coyote urine.
[4] CDCL-C consisted of CDCL and coyote urine.
[5] TMAD-CDCL-C consisted of TMAD 10% and CDCL.

CDCL, when used with M-44 NaCN ejectors, was significantly different ($P = 0.001$) when compared with results from leghold traps and cable snares. WU 15-20% produced significantly higher coyote capture rates when used with cable snares ($P = 0.01$) than with M-44 NaCN ejectors and leghold traps. Coyote capture rates attained when using SCC and WU Acids did not differ ($P > 0.05$) among the lethal devices.

SS results suggest EL's were successful in attracting coyotes to simulated coyote capture devices. SS data from 7 lures (TMAD 10%, RMO, SCC, EUF, WU 15-20%, WU Acids, and CDCL) were analyzed using ANOV to determine if differences exist between simulated coyote capture rates of trap rings and M-44 heads. The only lure showing significance ($P = 0.03$) was WU 15-20%, where trap rings produced higher simulated coyote capture rates than M-44 heads. RMO, when used with M-44 heads, produced a P-value very close to the 95% CI ($P = 0.053$) when compared with trap rings. The top 8 lures evaluated in SS producing the highest simulated coyote capture rates are presented in table 4.

Behavior

A total of 3858 behavioral responses from coyotes ($N = 2357$), carnivores ($N = 284$), herbivores ($N = 1183$), and birds ($N = 34$) was recorded. Coyote behaviors which showed the greatest seasonal variation from FW and SS were lure smelled, no other action (LS), rolling and/or shoulder rub (RSR), and licking, biting, and/or chewing (LBC) (fig. 1). The most frequently recorded coyote behavior and category was LBC behavior, producing 40.6% of FW and 35.6% SS responses (table 5). Coyote urination responses to EUF, WU 15-20%, WU Acids, and CDCL were analyzed using ANOV but no significance ($P > 0.05$) was found in either FW and SS. Four of the top 5 lures eliciting the RSR behavior of coyotes were EL's. CDCL, the only CL, generated the least seasonal variation in this behavioral response. No statistical difference ($P > 0.05$) was found in the FW or SS RSR behavior of coyotes elicited by TMAD 10%, SCC, EUF, WU 15-20%, and CDCL. An accelerated increase of 3.4-fold of the scratching and/or digging (SD) behavior of

Table 4.--The top 8 lures evaluated in SS producing the highest simulated coyote capture rates when used in conjunction with simulated lethal capture devices. Lures used with simulated capture devices generating <5 simuluated captured coyotes are not given.

Trap rings			M-44 heads			Break-away snare		
Lure	N coyotes captured	Capture rate	Lure	N coyotes captured	Capture rate	Lure	N coyotes captured	Capture rate
WU 15-20%	70	0.218	CFT	13	0.070	EUF	8	0.110
SLE	6	0.107	RMO	13	0.065			
CDCL	150	0.075	TMAD 10%	35	0.064			
CFT	31	0.047	CDCL	93	0.034			
EUF	40	0.028	TMAD 1%	16	0.030			

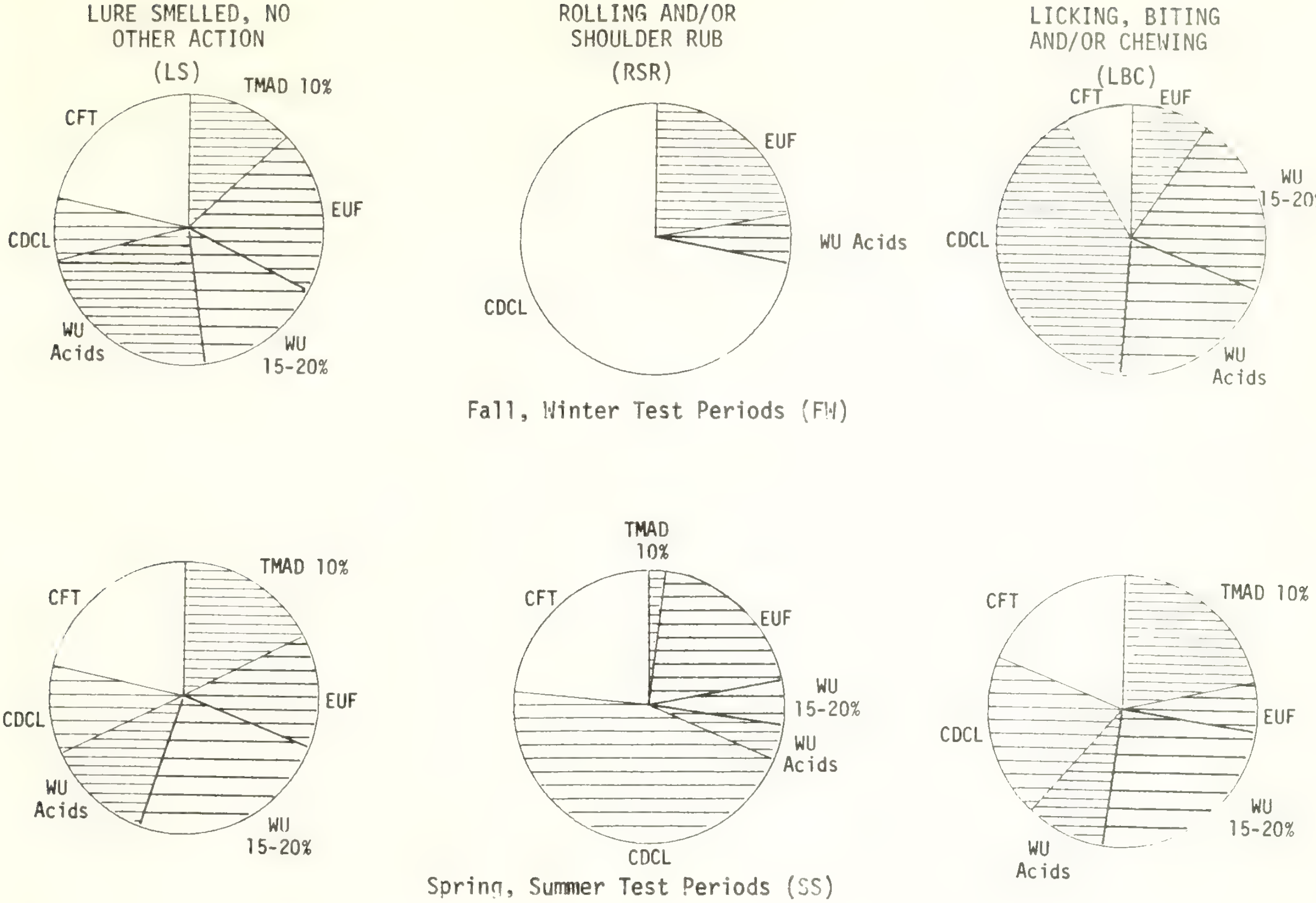

Figure 1.--Fall, winter (FW) and spring, summer (SS) seasonal variations of lure elicited coyote behaviors. Data provided in pie charts are from the comparison of 6 lures only; TMAD 10%, EUF, WU 15-20%, WU Acids, CDCL, and CFT.

FW LS behavior rates:

TMAD 10%=0.006	WU 15-20%=0.007	CDCL=0.003
EUF =0.009	WU Acids =0.011	CFT =0.010

SS LS behavior rates:

TMAD 10%=0.011	WU 15-20%=0.014	CDCL=0.006
EUF =0.008	WU Acids =0.008	CFT =0.013

FW RSR behavior rates:

TMAD 10%=0.000	WU 15-20%=0.000	CDCL=0.016
EUF =0.005	WU Acids =0.001	CFT =0.000

SS RSR behavior rates:

TMAD 10%=0.001	WU 15-20%=0.003	CDCL=0.020
EUF =0.009	WU Acids =0.002	CFT =0.011

FW LBC behavior rates:

TMAD 10%=0.000	WU 15-20%=0.020	CDCL=0.037
EUF =0.009	WU Acids =0.018	CFT =0.007

SS LBC behavior rates:

TMAD 10%=0.036	WU 15-20%=0.040	CDCL=0.032
EUF =0.010	WU Acids =0.016	CFT =0.031

Behavior rates are calculated by dividing the number of behavioral responses by the total number of presentations (or trapnights).

coyotes was generated in SS when comparing with FW. ANOV showed that Synthetic Porcupine Hair (SPH), TMAD 10%, WU Acids, CDCL, and (Carman's) Final Touch (CFT) significantly ($P < 0.05$) elicited the SD behavior more often in SS than in FW. Seven of 8 EL's increase the elicited LBC behavior of coyotes in SS while WU Acids decrease. Two of 3 CL's demonstrate a decrease of the LBC behavior in SS, but CFT produced higher LBC behaviors in SS.

EUF, WU 15-20%, WU Acids, and CDCL provided sufficient LBC behavior data for ANOV. FW coyote LBC behaviors from CDCL and WU Acids showed to be significantly higher than in SS, but no difference ($P > 0.05$) was found between seasons for LBC behavior elicited by EUF and WU 15-20%. EUF, WU 15-20%, WU Acids, and CDCL were analyzed using ANOV to determine if the FW LBC behavior was different among individual lures. The same lures, with the addition of CFT, were analyzed from SS. ANOV results indicate no statistical differences ($P > 0.05$) between LBC behaviors elicited in FW, but a difference was found in SS. CFT produced significantly higher LBC behaviors of coyotes than the other 4 lures ($P = 0.004$).

Table 5.--Coyote behavior response rates and seasonal ratios of experimental and superior commercial lures.[1]

Lure	[2]Presentations	[3]Behavior rate seasonal ratio					
		[4]LS	Urine	Defec	[5]RS	[6]SD	[7]LBC
TMAD 1%	199/1012	5:23	0:0	0:1	0:1	0:9	0:21
TMAD 10%	1188/1854	5:11	0:2	0:1	0:10	1:20	0:36
RMO	180/1045	11:23	0:0	0:1	0:3	6:9	0:22
SCC	814/2126	4:17	1:1	0:2	0:4	0:10	0:17
SPH	169/711	6:18	0:3	0:0	0:10	0:13	0:13
EUF	101/2114	30:8	4:9	3:3	5:9	5:12	4:9
WU 15-20%	2410/1592	7:14	5:9	0:1	0:3	0:10	20:40
WU Acids	1520/2564	11:8	4:9	0:1	1:2	1:10	18:16
CDCL	5228/4767	3:6	2:7	0:3	16:20	2:23	37:31
CFT	411/861	10:38	0:17	0:2	0:10	0:24	7:30
SB	783/661	3:2	0:0	0:0	6:2	2:0	31:12

[1] SLE, WU 1%, WU 10%, WU 10% + sugar, and SCC + sugar were not listed in Table 5 due to low presentation in FW and/or SS test periods.

[2] Sum of seasonal presentation. FW data is given first followed by SS data.

[3] Behavior rate seasonal ratio is calculated by dividing coyote responses by presentations and multiplying by 1000 to give behavior responses per 1000 presentations. FW rates are presented first in the ratio followed by SS rates.

[4] LS (lure smelled, no other action) was recorded if the coyote had entered the treatment site and approached the lure delivery material within a distance of no less than 30 cm without being captured.

[5] RSR = rolling and/or shoulder rub.

[6] SD = scratching and/or digging.

[7] LBC = licking, biting, and/or chewing.

Predator control techniques are most effective with lures which elicit either sniffing (lure smelled) or licking, biting and/or chewing response, and least effective with lures that elicit the rolling and/or shoulder rub (Scrivner et al. 1987). Coyote behavior required for efficient use of leghold traps and snares should be a compelling interest which interrupts other activities in which the coyotes are engaged, lowering coyote's normal caution, evoking approach, and ensuring interaction with the control device. The exhibited coyote behavior, which most likely represents the above list, was categorized into the LS behavior. All EL's evaluated in both seasons (FW and SS), except for EUF and WU Acids, generated higher LS coyote behaviors in SS. CL's generating the highest LS behavior and satisfying criteria for SS use with leghold traps and snares were CDCL and CFT. Turkowski et al. (1979, 1983) and Fagre et al. (1983) found similar results in testing CDCL with wild and captive coyotes respectively. In comparing CDCL with TMAD, Fagre et al. (1983) recorded higher coyote summer visit rates for CDCL. The results of this evaluation found the opposite in that TMAD 1% and 10% generated higher LS behavior rates than CDCL.

Ideal lures used with M-44 NaCN ejectors should elicit the LBC behavior of coyotes (Timm et al. 1977), possess the compelling holding interest properties, and be selective and highly attractive to coyotes during all seasons (Fagre et al. 1983). Results from lure evaluations conducted by Fagre et al. (1983) and Scrivner et al. (1984) found no lures that consistently elicited all behavioral properties required for M-44 NaCN ejectors in all seasons. EL's evaluated in this study meeting the above criteria and exhibiting high SS LBC behaviors of coyotes were WU 15-20%, TMAD 10% and 1%, Rotten Meat Odor (RMO), and SCC. However, lures producing consistent LBC behaviors of coyotes in all seasons (FW and SS) were WU Acids and CDCL. Turkowski et al. (1979) found the same results for CDCL and listed it as a superior coyote lure consistently eliciting the LBC behavior during all seasons.

Temperature

ANOV found no significance ($P > 0.05$) between FW temperature ranges of coyote capture rates for EUF, WU 15-20%, WU Acids, CDCL, and Stokers Bounty (SB). However, SS data for the same lures were analyzed, and results found that WU Acids was the only lure that showed significant differences ($P = 0.003$) in simulated coyote capture rates and temperature ranges. The temperature range of 10.0 - 15.0 C produced higher simulated coyote capture rates than other temperature ranges. Lures producing high simulated coyote capture rates in SS at high temperatures (21.1 - 26.1 C) were TMAD 10%, and SB. Lures producing high coyote capture rates in FW at low ambient

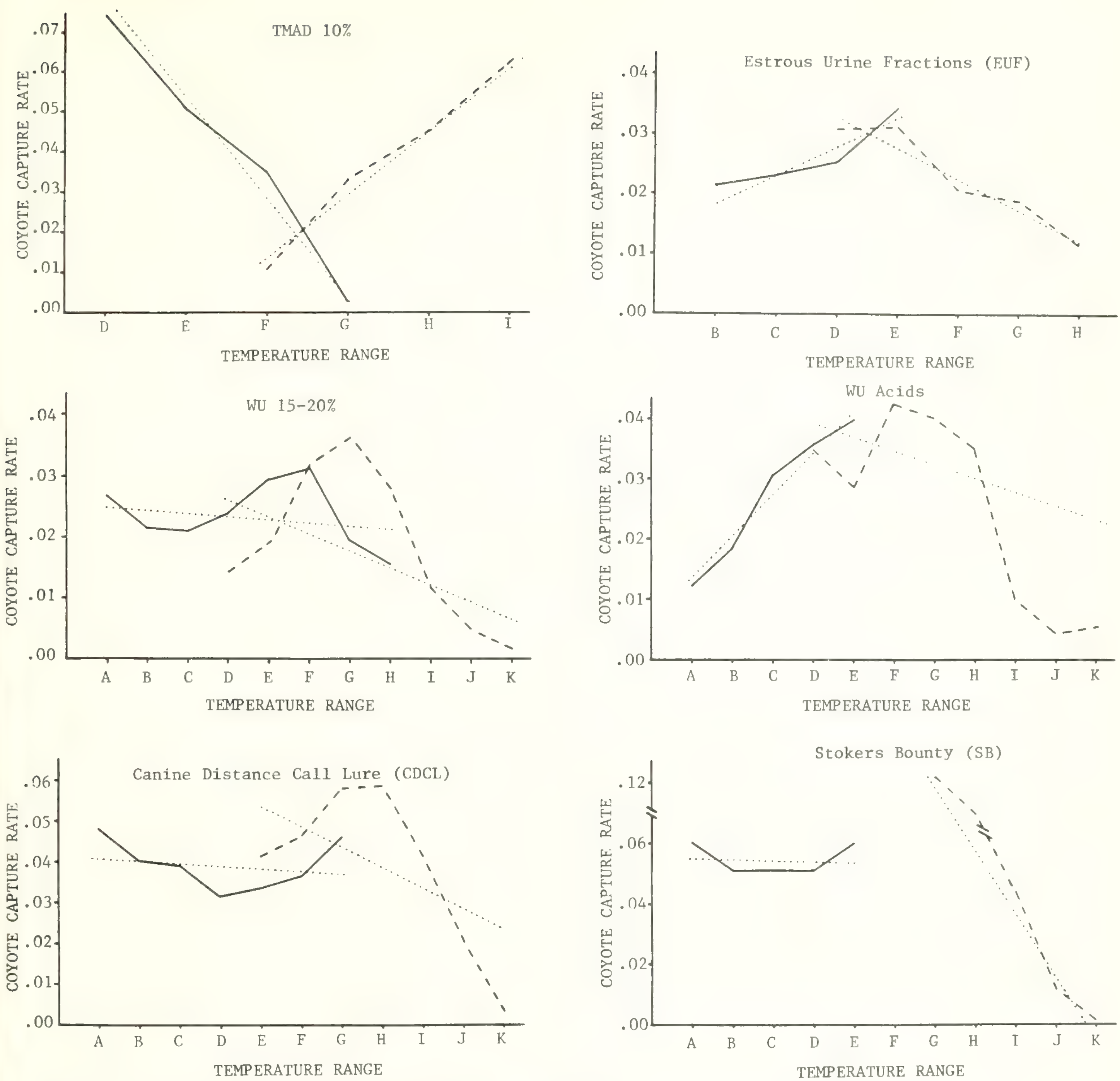

Figure 2.--Bivariate linear regression analysis for TMAD 10%, EUF, WU 15-20%, WU Acids, CDCL, and SB capture and simulated capture rates for temperature ranges. Solid, dashed, and dotted lines represent fall and winter (FW) data, spring and summer (SS) data, and predicted regression line respectively. Symbols for temperature ranges are: A=-23.3 to -18.3, B=-17.8 to -12.8, C=-12.2 to -7.2, D=-6.7 to -1.7, E=-1.1 to 3.9, F=4.4 to 9.4, G=10.0 to 15.0, H=15.6 to 20.6, I=21.1 to 26.1, J=26.7 to 31.7, K=32.2 to 37.2 C. Predicted regression equations are presented below.

Lure	Season	Regression equation	R^2 value
TMAD 10%	FW	Y=0.1650 - 0.0227(X)	98.1%
TMAD 10%	SS	Y=0.0890 + 0.0165(X)	98.6%
EUF	FW	Y=0.0123 + 0.0040(X)	90.3%
EUF	SS	Y=0.0529 - 0.0050(X)	92.7%
WU 15-20%	FW	Y=0.0266 - 0.0007(X)	8.2%
WU 15-20%	SS	Y=0.0387 - 0.0027(X)	26.9%
WU Acids	FW	Y=0.0057 + 0.0073(X)	95.1%
WU Acids	SS	Y=0.0635 + 0.0051(X)	60.1%
CDCL	FW	Y=0.0418 - 0.0007(X)	5.7%
CDCL	SS	Y=0.0893 - 0.0064(X)	48.7%
SB	FW	Y=0.0540 - 0.0006(X)	1.3%
SB	SS	Y=0.3410 - 0.0322(X)	95.5%

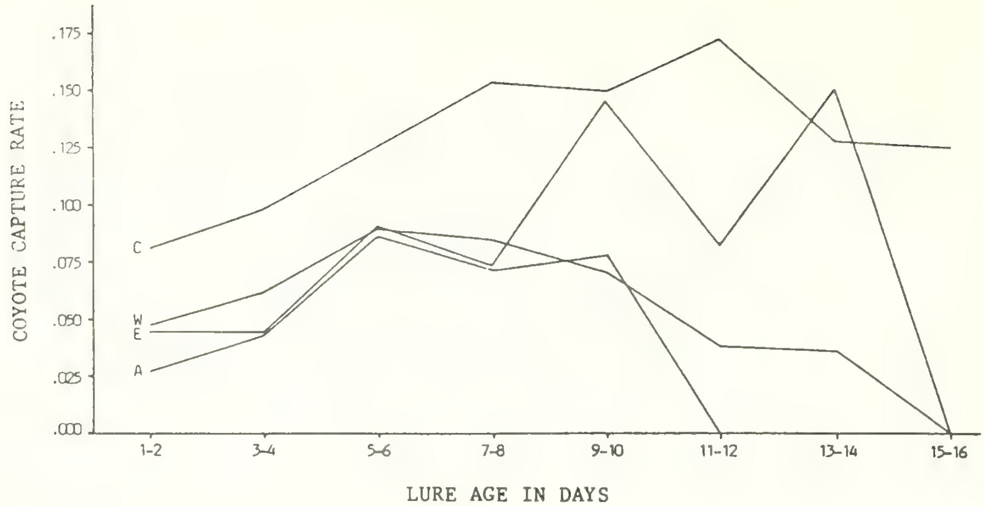

Figure 3.--FW coyote capture rates of WU 15-20%, WU Acids, EUF, and CDCL plotted against lure age. W=WU 15-20%, A=WU Acids, E=EUF, and C=CDCL.

temperatures (-23.3 to -18.3 C) were WU 15-20%, CDCL, and SB.

Bivariate linear regression analysis was conducted on TMAD 10%, CDCL, EUF, WU 15-20%, WU Acids, and SB data from FW and SS to determine stability of coyote capture and simulated capture rates of temperature gradients (fig. 2). FW analysis suggest that the temperature fluctuation had very little effect on WU 15-20%, CDCL, and SB in attracting coyotes. SS regression analysis for TMAD 10%, EUF, WU 15-20%, WU Acids, CDCL, and SB indicate a varying degree of stability and that simulated coyote capture rates decreased as temperature increased. However, TMAD 10% exhibited a positive slope and simulated coyote capture rates increased as temperature increased. Regression analysis for TMAD 10% provided a R^2 value of 98.6% which suggests very little fluctuation and precision in simulated coyote capture rates. In comparing lures with overall annual stability of capture rates, (FW and SS), EUF, WU 15-20%, and CDCL appear to be broad based and least affected by changes in temperatures.

Lure Age

FW test periods produced 8 lure age classes with 28.1% of coyotes (N = 52) being captured in the 5-6 day lure age class, followed by 25.9% (N = 48) captured in the 3-4 day lure age class. ANOV was conducted to determine if a difference exists between coyote capture rates and lure age classes. Three lures were evaluated from FW, and no significant difference ($P > 0.05$) was found between capture rates of coyotes and lure age classes for WU 15-20%, WU Acids, and CDCL. Capture rates from WU 15-20%, EUF, WU acids, and CDCL were plotted against lure ages (fig. 3). A 3 point running average was applied to the mean in an effort to reduce graphic fluctuations.

SS results generated 11 lure age classes with 28.8% of simulated coyote captures (N = 119) from the 1-2 day age class. ANOV results of WU 15-20%, WU Acids, and CDCL data show no difference ($P > 0.05$) between simulated coyote capture rates and lure age classes. Simulated coyote capture rates from SCC, CDCL, EUF, WU 15-20%, and WU Acids were plotted against lure age classes (fig. 4) after applying a 3 point running average to the mean rates. All lures illustrate a pattern of (a) increase, (b) leveling off, and (c) decrease of simulated coyote capture rates, with EUF, SCC, and WU Acids exhibiting prolonged patterns of b.

Lunar Phase and Barometric Movements

No statistical differences ($P > 0.05$) were found for lunar phase and barometric movements of lures, suggesting that these 2 variables have little relative effect on attractiveness of lures to coyotes or coyote selectivity. Although ANOV found no significant relationship between FW barometric movements for lures and capture rates of coyotes, an overall trend was apparent. The FW rising and falling barometric categories consistently generated higher coyote capture rates than did the stable barometric movement. These trends were not evident in SS.

SUMMARY AND CONCLUSION

The probability of eliminating a specific depredating coyote is increased by optimizing the interaction of coyote behavior, chemicals, capture devices, and lures. Forty-five experimental and commercial lures were evaluated in the field to increase the efficacy and selectivity of leghold traps, M-44 NaCN ejectors, snares, and other control devices. A total of

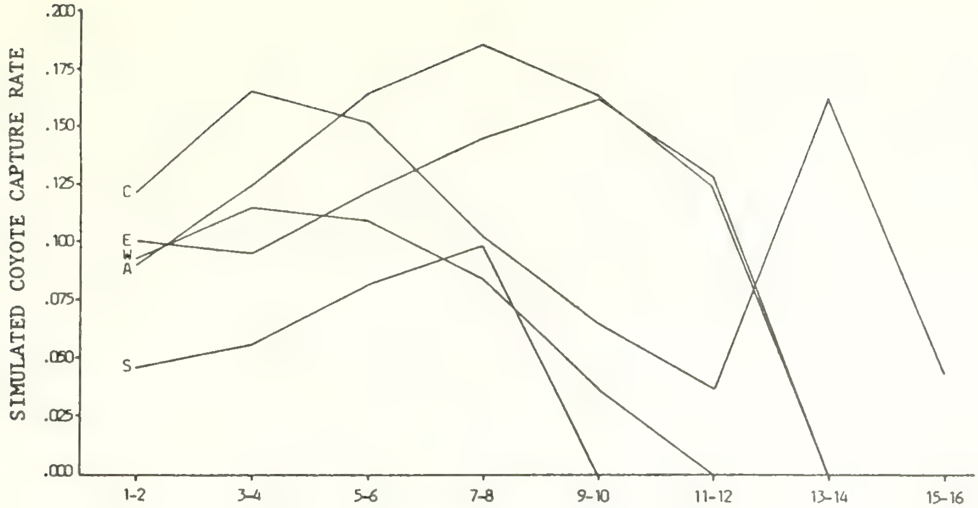

Figure 4.--SS simulated coyote capture rates of SCC, WU 15-20%, EUF, WU Acids, and CDCL plotted against lure age. S=SCC, W=WU 15-20%, E=EUF, A=WU Acids, and C=CDCL.

609 coyotes were captured in 15 FW test periods containing 25,478 trapnights. The top 9 lures representing the highest coyote capture rates when used in conjunction with (a) leghold traps, (b) M-44 NaCN ejectors, and (c) cable snares were (Carman's) Final Touch Combo (CFT-C), Combo 5, and Combo 6; (O'Gorman) Long Distance Call (OLDC), (Carman's) Canine Distance Call Lure (CDCL), and (O'Gorman) Wolfer Scent (OWS); Olmstead Coyote Lure (OCL), Estrous Urine Fractions (EUF), and WU 15-20% respectively. A total of 731 coyotes responded to simulated coyote capture devices from 15 SS test periods consisting of 20,686 trapnights. The top 7 lures producing the highest simulated coyote capture rates when evaluated with (a) trap rings, (b) M-44 heads, and (c) break-away snares were WU 15-20%, Sheep Liver Extract (SLE), and CDCL; (Carman's) Final Touch (CFT), Rotten Meat Odor (RMO), and TMAD 10%; and EUF respectively.

EL's produced the widest seasonal variance in individual elicited behaviors of coyotes, while the superior CL's educed somewhat consistent seasonal coyote behaviors. Ambient temperature is considered to be the most influential weather variable regarding lure attractiveness to coyotes and efficacy of capture devices. Analysis of lunar phase and barometric movement data suggests these variables have little influence in the attractiveness of lures to coyotes and efficacy of capture devices. Lure age suggests that certain EL's and CL's produce a short-time limit in coyote attractiveness, while others are effective up to and beyond 2 weeks in FW and SS.

EL's worked efficiently with leghold traps, snares, and M-44 NaCN ejectors in a well planned and delivered program, year round. CL's used in conjunction with EL's were also effective in year round applications of control devices.

CL's and EL's elicited different behaviors at different seasons in different coyotes, and the behaviors can be predicted. This makes all of the CL's and EL's potentially valuable when coupled with the optimum equipment and placement. The key is to be able to evaluate the depredation situation, present and prescribe the proper lure, optimum equipment, location, and arrangement of equipment to produce the maximum probability of removing depredating coyotes.

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Cougar Predation on Livestock in New Mexico, January 1983 Through June 1984[1]

Gary A. Littauer and Ronald J. White[2]

Abstract: A telephone survey was conducted in which the objective was to obtain information from the entire population of livestock producers in New Mexico who had losses to cougars (*Felis concolor*) in 1983 and the first six months of 1984. A total of 103 ranchers reported losses in 1983 and 60 reported losses in the first six months of 1984. Verified (by examination of kills) losses of sheep and lambs to cougars totaled 1,202 in 1983 and 525 in the first half of 1984. Verified losses of cattle and calves totaled 230 in 1983 and 102 in the first half of 1984. Suspected losses (not verified) of sheep and cattle were similar in number to verified losses. Other verified livestock losses reported were 3 goats and 4 colts in 1983, and 25 goats and 2 colts in the first half of 1984. The value of reported losses to cougars in 1983 was at least $125,000 (producer-verified losses) and may have been as much as $220,000 (when suspected losses are included). The data suggested statewide cougar predation losses are substantially underrepresented by the passive reporting system used by the New Mexico Department of Game and Fish (NMDGF). Respondents reported a total of 217 cougars that were taken to control predation on livestock in the 18 months covered by the survey; 49% were reportedly taken on sport hunting tags suggesting that sport hunting has been a major method used by ranchers to address cougar predation problems.

INTRODUCTION

In 1983 a bill was introduced to the New Mexico State legislature to remove the cougar from the list of game animals protected under the authority of the New Mexico Department of Game and Fish (NMDGF). Hearings were held by the New Mexico House Agriculture Committee and the Consumer and Public Affairs Committee to receive public input on the bill. Considerable polarization of viewpoints between representatives of various sportsmen and trapping organizations and members of the livestock industry on one hand, and environmental groups on the other, established the controversial nature of the bill.

Concerns were voiced by some members of sportsmen groups that cougars were causing excessive adverse impacts on big game populations. Ranchers claimed cougars were causing intolerable losses of livestock and that existing legal remedies to control the problem were inadequate. They indicated some ranchers may not always report cougar predation problems to the NMDGF and may handle their own cougar predation problems. Environmental groups believed little was known about the status of cougar populations in New Mexico and requested that no cougars be killed until adequate knowledge was available to assure that cougar populations could safely withstand human-caused mortality. The NMDGF reported the status of cougar populations in New Mexico was largely unknown.

As a result of the hearings, the committees concluded inadequate information existed to make

[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop [Rapid City, South Dakota, April 28-30, 1987].

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a decision on the bill. House Memorial 42 (HM 42) was passed requesting the NMDGF to study the status of cougar populations and the cougar predation problem. As part of its effort to respond, the NMDGF requested New Mexico Department of Agriculture (NMDA) assistance in developing a response to HM 42. NMDA conducted a survey of ranchers to determine the extent of cougar predation on livestock. This paper describes the methodology and results of the survey.

We thank D. Gerhardt, C. Hayes, and M. Owens of the U.S. Department of Agriculture/ New Mexico Agricultural Statistics Service (USDA/NMASS) for help in survey and questionnaire design and for use of telephone services. T. Stephenson and G. Aldrich assisted with telephone interviews. R. Owens and J. Knight provided suggestions on questionnaire design and reviewed earlier drafts of this manuscript. V. W. Howard also reviewed the manuscript. We also thank the county extension agents, Animal Damage Control (ADC) specialists of the cooperative ADC program between NMDA and the USDA-Animal and Plant Health Inspection Service (APHIS) and the ranchers who cooperated to provide names and information for the survey.

METHODS

A list of ranchers with cougar predation problems was developed by soliciting names from (1) ADC specialists in the cooperative ADC program; (2) county extension agents; and (3) ranchers as they were contacted in the survey. The goal of this effort was to attempt to contact every rancher in New Mexico who had experienced cougar predation problems in calendar year 1983 or in the first six months of 1984. Although every impacted rancher was probably not contacted, the effort should have provided a minimum estimate of the extent of cougar predation problems during the specified periods. The major advantage of this survey methodology was reduced sampling error. Since the goal was to obtain information from the entire population (i.e., all ranchers with cougar problems), normal sampling problems were eliminated.

Attempts were made to contact each rancher on the list by telephone, in person, or by mail. Telephone interviews were conducted by NMDA personnel and personnel of the USDA/NMASS. Questions were asked to obtain information on the following subjects:

1. The number and class of livestock lost to cougars in 1983 and in the first half of 1984 that the rancher, his or her employees, or government agency personnel verified by personal examination of the carcasses.

2. The number and class of suspected but unverified livestock lost to cougars in each of the above time periods.

3. The county of the rancher's enterprise where cougar losses were experienced.

4. The number of cougars killed to control predation on livestock in 1983 and in the first half of 1984.

5. The number of cougars killed for depredation control that were taken on sport hunting tags.

6. The names and telephone numbers of additional ranchers who may have experienced cougar problems.

7. Other comments.

When telephoning was near completion in late July 1984, notices were printed in newsletters of the New Mexico Cattle Growers' Association, New Mexico Wool Growers, Inc., New Mexico Farm and Livestock Bureau, and in the New Mexico Stockman magazine. The notices requested affected ranchers who had not been contacted to contact NMDA by September 1, 1984.

A list of 209 names was developed for contacting in the survey. Twenty-six ranchers could not be reached by telephone or in person. These 26 producers were mailed a questionnaire with a letter asking them to either complete the questionnaire and return it, or to call NMDA toll-free with their information before September 1, 1984.

Respondents in the survey were assured their individual responses would be held confidential and only totals, averages, and percentages would be used in the report.

USDA/NMASS (personal communication) provided economic data used to estimate livestock values.

RESULTS

A total of 114 ranchers in 17 counties (Fig. 1) reported losing one or more head of livestock to cougars during the 18 months covered by the survey; 103 reported experiencing losses in 1983 and 60 reported losses for the first half of 1984. Forty-nine ranchers reporting losses to cougars in 1983 also had losses in the first half of 1984.

No contact was made with the 26 ranchers who were mailed questionnaires. Sixty-eight ranchers reported they either had no losses, or they were unaware of any losses to cougars during the specified periods. One rancher refused to answer specific questions although he indicated experiencing losses to cougars.

Sheep Losses

Information obtained on sheep losses to cougars is summarized in Table 1. In 1983, about 50% of the ranchers with losses and 33% of the verified losses were in Lincoln County. Eddy County contained nearly half (48%) of the total verified sheep losses but contained only 18% of the ranchers with losses. Consequently, Eddy County experienced the highest mean number lost per rancher. The number of verified losses per affected rancher in the survey ranged from 1 to 306 indicating high variability among ranchers. Over 25% of the total verified sheep and lamb losses in 1983 were reported by one rancher in the survey.

Southeastern New Mexico contained the majority of known cougar predation problems on sheep; nearly 97% of the total verified losses of sheep and lambs occurred in southeastern counties (Chaves, Otero, Lincoln, and Eddy). We located only three sheep ranchers in northern New Mexico who suffered losses to cougars.

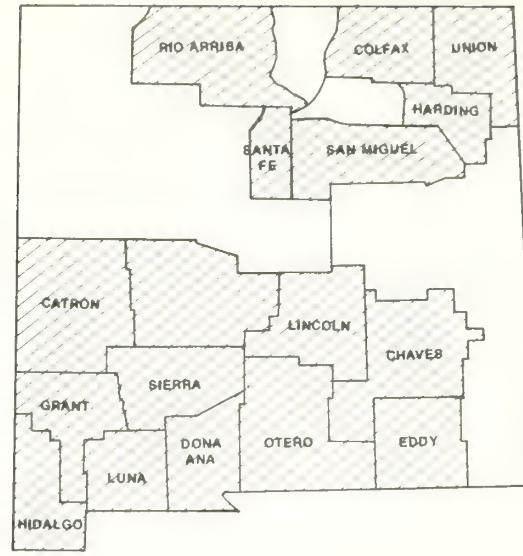

Figure 1.--New Mexico counties with reported livestock losses to cougars in 1983 or the first six months of 1984.

Table 1.--Summaries of sheep and lamb losses to cougars in New Mexico reported by ranchers for 1983 and the first half of 1984.

Calendar Year 1983

County	No. of Ranchers With Losses		Total No. of Sheep & Lambs Lost		Mean No. Lost Per Rancher		Total Dollar Value[3]	
	V[1]	V+S[2]	V	V+S	V	V+S	V	V+S
Harding	1	1	15	15	15	15		
San Miguel	1	1	14	14	14	14		
Santa Fe	1	1	8	8	8	8		
Chaves	4	5	184	606	46.0	121.2		
Otero	2	2	5	5	2.5	2.5		
Lincoln	14	18	395	904	28.2	50.2		
Eddy	5	6	581	728	116.2	121.3		
Statewide	28	34	1202	2280	42.9	67.1	$55,833	$105,742

First Half of 1984

County	V	V+S	V	V+S	V	V+S	Total Dollar Value V	Total Dollar Value V+S
Chaves	2	2	88	338	44.0	169.0		
Lincoln	6	9	216	468	36.0	52.0		
Eddy	4	4	221	326	55.3	81.5		
Statewide	12	15	525	1132	43.8	75.5	$24,671	$52,583

[1]V = losses reportedly verified by examination of carcasses.
[2]V + S = verified losses plus losses that were suspected but not verified by examination of carcasses.
[3]Value of lambs was $45.09 per head based on assumed average weight of 90 lbs. per head and average price of $50.00 per 100 lbs. (USDA/NMASS). Average 1983 inventory value of adult sheep was $47.50 per head (USDA/NMASS).

Sheep losses in the first half of 1984 were proportionately similar (on a temporal basis) to losses in 1983. Forty-three percent of the ranchers experiencing verified losses in 1983 experienced losses in the first six months of 1984. Total losses (verified plus suspected) in the first half of 1984 were 44% of those reported for 1983. The mean number of sheep lost per rancher also was similar between 1983 ($\bar{x}$=43) and the first half of 1984 ($\bar{x}$=44). The same counties where the majority of losses occurred in 1983 also experienced losses in 1984.

Cougars caused more losses of adult sheep than of lambs; 63% of the total verified losses of sheep and lambs for the 18 months was of adult sheep; 64% of the dollar value of those losses was in adult sheep.

Cattle Losses

Data obtained on cattle losses to cougars is summarized in Table 2. Numbers of cattle losses were substantially less than sheep losses but dollar values were higher. The value of verified cattle losses was nearly 24% greater than the value of verified sheep losses in 1983.

Cattle losses as determined by the survey also were distributed more widely than sheep losses in 1983, occurring in 12 counties (as

Table 2.--Summaries of cattle losses to cougars in New Mexico reported by ranchers for 1983 and the first half of 1984.

County	No. of Ranchers With Losses		Total No. of Cattle Lost		Mean No. Lost Per Rancher		Total Dollar Value[3]	
	V[1]	V+S[2]	V	V+S	V	V+S	V	V+S
Calendar Year 1983								
Grant	17	17	78	93	4.6	5.5		
Hidalgo	3	4	17	33	5.7	8.3		
Socorro	5	5	24	37	4.8	7.4		
Catron	11	12	37	60	3.4	5.0		
Sierra	11	11	36	60	3.3	5.5		
Luna	1	1	1	4	1	4		
Dona Ana	1	1	6	20	6	20		
Harding	1	2	2	8	2	4.0		
Union	1	1	1	1	1	1		
Colfax	1	2	1	2	1	1		
Lincoln	5	6	16	32	3.2	5.3		
Eddy	4	4	11	28	2.8	7.0		
Rio Arriba		1		2		2		
Chaves		1		11		11		
Statewide	61	68	230	391	3.8	5.8	$68,988	$116,349
First Half of 1984								
Grant	9	9	22	44	2.4	4.9		
Hidalgo	3	3	10	10	3.3	3.3		
Socorro	2	4	2	32	1.0	8.0		
Catron	7	9	32	62	4.6	6.9		
Sierra	5	6	15	25	3.0	4.2		
Dona Ana	1	1	1	3	1	3		
Colfax	1	1	1	5	1	5		
Lincoln	3	4	14	34	4.7	8.5		
Eddy	3	5	5	16	1.7	3.2		
Harding		1		4		4		
San Miguel		1		2		2		
Rio Arriba		1		3		3		
Statewide	34	45	102	240	3.0	5.3	$30,826	$71,495

[1]V = losses reportedly verified by examination of carcasses.

[2]V + S = verified losses plus losses that were suspected but not verified by examination of carcasses.

[3]Value of calves was $293.00 per head based on 1983 price per 100 lbs. of $65.20 and assumed average weight of 450 lbs. at marketing (USDA/NMASS). Value of cows and yearlings assumed equal to average 1983 inventory value of $340 per head (USDA/NMASS)

opposed to 7 counties for sheep losses). Approximately twice as many cattle ranchers (61) as sheep ranchers (28) were affected by verified cougar predation in 1983. However, mean number of cattle lost per affected rancher ($\bar{x}$ = 3.8) was substantially less than the mean number of sheep lost per affected rancher ($\bar{x}$ = 43). The range of verified cattle numbers lost per affected rancher was 1-12.

Most cattle losses occurred in the southwestern quarter of New Mexico. Grant, Hidalgo, Socorro, Catron, Sierra, Luna, and Dona Ana counties, which comprise that quadrant of the state, contributed 83% of the total verified cattle losses to cougars for the entire state. About 12% occurred in southeastern New Mexico and the remaining 1% occurred in the northeastern quarter of the state.

In contrast to sheep loss data, cougars caused greater losses of young than of adult cattle. Calves comprised 84% of the verified cattle losses and 82% of the dollar value of cattle lost to cougars in the survey.

Other Livestock Losses

Two ranchers reported losing domestic goats to cougars. One rancher from Union County claimed a verified loss of 25 goats to cougars in the first half of 1984. Another from Sierra County claimed a verified loss of three goats to cougars in 1983.

Three ranchers claimed verified losses of a total of four colts in 1983. Another rancher suspected a colt he lost in 1983 was due to a cougar but did not verify the cause. One rancher reported he verified the loss of two colts to cougars in the first half of 1984.

Cougars Killed For Livestock Protection

Data on cougar mortalities reported by ranchers in the survey are shown in Table 3.

Table 3.--Summaries of cougars killed to protect livestock in New Mexico as reported by ranchers for 1983 and the first half of 1984.

Area Within State	No. Killed		No. on Sport Tags		No. of Ranchers Unwilling to Report [1]
	1983	First Half 1984 [2]	1983	First Half 1984	
Northwest, includes: Rio Arriba, Santa Fe counties	1	0	0	0	0
Northeast, includes: Union, Harding, Colfax, San Miguel, Quay counties	8	1	3	1	2
Southwest, includes: Grant, Hidalgo, Socorro, Catron, Sierra, Luna, Dona Ana counties	77	38	52	26	5
Southeast, includes: Chaves, Otero, Lincoln, Eddy counties	65	27	21	4	4
Statewide Totals	151	66	76	31	11

[1]Ranchers who indicated taking cougars for depredation control but would not divulge numbers or whether the cougars were taken on sport tags.
[2]Encompasses the first six months of 1984.

About 53% of cougars killed to protect livestock were taken in southwestern New Mexico while 42% were taken in southeastern New Mexico. In total, 95% of the reported cougars killed were taken in the southern half of the state. Approximately half (49%) of the cougars killed to protect livestocl. were reportedly taken on sport hunting tags. Eleven ranchers indicated they killed cougars for depredation control but would not divulge numbers.

DISCUSSION

Surveys of farmers and ranchers to quantify predation losses have been criticized as being potentially inaccurate. Producers seldom perform necropsies on dead animals, whereas necropsies are performed in biological damage assessment studies. Instead, producers often determine the cause of death by observation of the carcass and the site where the carcass is located. Doubtful cases or missing animals may be attributed as losses to the most likely cause based on experience or the circumstances at the time. For example, if the weather has been comfortable, missing lambs would not be attributed to the effects of cold, damp temperatures. Thus, more judgement is involved with ranchers' determinations of losses than in biological assessments. This factor must be considered in evaluating survey data. We attempted to resolve this problem by specifically requesting numbers of losses verified by examination of kills, as distinguished from suspected losses due to circumstantial evidence.

DeLorenzo and Howard (1977) reported that losses of sheep and lambs to predators, verified by trained biologists using radio telemetry on a range lambing operation in New Mexico, were similar to losses reported by the rancher on questionnaire surveys in two previous years. Gee et al., (1977) reported on results of a survey conducted by USDA to estimate sheep and lamb losses to predators and other causes in the western United States and provided the following observation: "Too few ranches have been included in biological damage assessment studies to permit generalization as to overall loss levels which could be statistically compared with those of the producer surveys conducted for this study. The most that can be observed so far is that the loss levels found on the few damage assessment ranches and those reported by surveyed producers appear to be generally compatible." These studies suggest rancher surveys can provide acceptable data on livestock losses to predators.

Although this type of survey cannot determine the accuracy of the response information, some general impressions were obtained by the senior author who conducted telephone interviews with approximately one-third of the respondents. Most of these ranchers would not attribute unknown losses to cougars. Many ranchers reported a number of cougar-caused losses that were verified, and implied they may have experienced other losses to cougars, but were not willing to classify them as suspected losses. These responses indicated the ranchers did not exaggerate reported losses to emphasize the importance of their problems.

A few ranchers did not know the extent of their losses to cougars, but due to circumstantial evidence, believed they had suffered losses. Achieving smaller calf crops in pastures they knew were frequented by cougars compared to calf crops obtained in pastures not considered to be habitat for cougars is an example of circumstantial evidence suggesting losses to cougars. Although these ranchers could have classified these as estimated "suspected" losses to cougars, we did not include this information to remain conservative in our estimate of total statewide losses.

We located only one rancher with cougar-caused losses in northwestern New Mexico. Approximately one-third of that quadrant is Indian reservations and we did not attempt to contact them. Therefore, losses in that quadrant may be underrepresented in survey totals.

Suspected sheep losses were nearly equal in number (1685) to verified losses (1727) in the 18-month period covered by the survey. Similarly, suspected cattle losses (299) were approximately equal to verified losses (332) reported over the same period. This information suggests ranchers only verify about half of the losses they may experience.

Certain individual sheep ranchers suffered substantially greater economic losses than individual cattle ranchers. The greatest individual loss reported by a sheep rancher was about $14,000 for verified losses in 1983 while the greatest verified cattle loss reported by an individual was about $4,000. Economic losses were not evenly distributed among ranchers suffering cougar predation problems.

Evans (1983) reported a 10-year average (1973-82) of 11.2 ranchers in New Mexico reporting cougar depredation incidents to the NMDGF. Evans reported the average total statewide value of annual livestock losses to cougars was $29,500. NMDA's survey, however, indicated the statewide value of losses in 1983 was at least $125,000 (verified losses) and may have been $220,000. These data suggested the passive reporting system (using unsolicited reports) of the NMDGF underrepresented actual losses by as much as 87%.

This survey provided minimum estimates because all ranchers with livestock losses to cougars may not have been surveyed. The range of estimated dollar losses caused by depredating cougars in the first half of 1984 was consistent with 1983 suggesting economic losses for 1983

and 1984 would have been similar had we obtained data for all of 1984.

Our estimates of economic losses by ranchers because of cougar depredations do not include various indirect costs including extra management practices, veterinarian bills, and predator control. Therefore, our estimates underrepresent the adverse financial impact of cougars on affected ranchers. For example, one respondent suffered no losses of livestock, but owned two high-valued horses that were attacked by a cougar. This individual reportedly spent approximately $8,000 on horse stalls solely for protection against cougars. These types of costs are not included in the total dollar loss estimates.

Approximately 50% of the cougars that ranchers reported were taken for controlling predation in 1983 and the first half of 1984 were taken on sport hunting tags. This suggested that ranchers relied heavily on licensed sport hunting to address cougar predation problems. Therefore, reduction of sport hunting seasons may adversely impact the ability of some ranchers to control cougar predation problems when they rely on cougar hunting guides with licensed sport hunters to take problem cougars.

The NMDGF recommended the New Mexico State Legislature appoint a study group to examine various mitigation alternatives, including compensation of ranchers for losses, in addressing cougar predation problems. Although it is unknown whether 1983 and the first half of 1984 are "average" years with regard to cougar predation problems in New Mexico, the results of this survey provide an indication of the potential funding requirements for compensation of losses.

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Snaring as a Beaver Control Technique in South Dakota[1]

Jerry Riedel[2]

Abstract.--Methods used for alleviating beaver damage include suggestions on farm management, extension trapping, and direct control. Direct control is utilized in the majority of the complaints with snaring constituting the most often used control technique.

The region of responsibility for my animal damage control work in South Dakota is the ten counties in the northeast corner of the state, encompassing 7,184 square miles.[3] Geographic features include the glacial produced Lakes Region, Coteau Hills, two rivers, numerous streams and drainages, all four types of wetlands, and farm and pasture land.

The Lakes Region includes 257 natural lakes totaling approximately 198,000 acres of water (Anonymous, 1973). The shorelines are surrounded with various species of deciduous trees which provide good beaver habitat.

The Coteau Hills is a rough highland extending from the North Dakota border southward for about 200 miles.[4] This highland forms a "hogsback" approximately 25 miles wide with an elevation of over 2,000 feet above sea level (Schell, 1968). Wooded coulees rise above the streams coming down the eastern side of these hills. These drainages feed into larger streams as they reach the flats.

On the flats there are gentle rolling hills and level farm country that is intersected by the Little Minnesota River and the Sioux River along with the Twin Brooks, Whetstone, Yellowbanks, and other various smaller tributaries. All these features add much diversity to the region while at the same time making it very suitable for beaver and very susceptible to beaver damage.

I divide my beaver damage problems into three categories: cutting, flooding, and eroding. From a total of the last 500 beaver complaints worked on 46 per cent were from the cutting of trees and corn (of which 94 per cent involved trees). Also 46 per cent of the complaints involved the beaver controlling water levels by either preventing the flow from going downstream, or the flooding of the upstream. Beaver eroding earthen structures such as road grades, railroad beds, sewage lagoons, and stream and lake banks totaled 8 per cent of the total complaints.

The geographic and the damage diversity necessitates various approaches to solving beaver damage problems. on 4 per cent of the total complaints I have suggested changes in farm management practices. For example, I have recommended the use of woven wire or electric fencing around a shelterbelt or cornfield for beaver exclusion. I have recommended the use of an electric fence to prevent beaver from repairing a torn hole in the dam. Lowering the water level with the use of an installed trickle tube can be another form of farm management. Screening or wrapping of individual trees is another example. However, these methods give only temporary relief at best.

Approach method two is the extension approach. I handle approximately 10 per cent of the complaints in this manner. I will assist in locating a private trapper to do the control work or will give individual instructions to private trappers or to the complainee.

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[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop (Rapid City, South Dakota, April 28-30, 1987).

[2]Jerry Riedel is Extension Trapper, Department of Game, Fish and Parks, Watertown, SD

[3]Anonymous - 1973, South Dakota Geographic Names, Brevet Press, Sioux Falls, South Dakota

[4]Schell, Herbert S. 1968. History of South Dakota, University of Nebraska Press, Lincoln, NE.

The approach I use most often on beaver damage is direct control, where I eradicate the beaver myself. For my direct control work I use the snare the most often. I take approximately 95 per cent of my beaver in snares, about 3 per cent of the beaver are taken with leghold traps, one per cent are trapped with bodygrips, .5 per cent are taken in live traps and .5 per cent are shot. Snares are very effective on beaver and have the advantage in that they are quite versatile and are quick and easy to use. With snares you do not scare or spook the beaver and the nontarget catches are just about nonexistent.

For the snare itself I prefer a 36 inch length of 7x7 3/32 inch cable, a Gregerson swivel and either a Hoffman or Gregerson lock. An S-hook attaches the snare to a second swivel on a four foot length of chain which rotates around the anchoring stake. The short snare and second swivel on the chain will help prevent the snare from being kinked or frayed after a catch is made. Wire will bend and break and should not be used for anchoring a snare.

I use two different types of stakes. A three foot length of 3/8 inch rod is used for firm soils such as sod or partially frozen ground, and a three foot length of 3/4 inch diameter pipe is used for soft or spongy ground. Where available I will attach my chain to a tree or other immovable structures that are present for a means of anchoring the catch.

To support the snares a length of baling wire 14 inches long is crimped and wrapped on the snare near the swivel. The other end of the baling wire is then attached to a support stick, placed upright in the ground. There should only be 4 to 6 inches of slack left in the baling wire allowing the snare to pull tight quickly. The baling wire is light enough to allow flexibility for centering the snare in its exact setting position, but yet is strong enough to support the suspended snare.

The imitation castor mound has been the most productive snare set for me. It offers good eye appeal as well as having the attractability from the odor of the lure. If possible I select a slightly elevated bank as this adds to the visibility of this set. Wind direction is also very important when selecting a location for this set. I've caught many beaver on eye appeal alone but the success is much greater when the wind carries the odor of the lure to the beaver. In making the set slick up the bank with mud and build a small mound about 2 to 3 inches high with mud, and sticks, leaves or grass. Dead branches are used for guide sticks and are pushed into the mud about 6 inches apart and angling away from the bank. Build this fence about 2 feet out along the shoreline on each side from the center of the castor mound. This will prevent the beaver from working the set from the sides. This fence is more or less V-shaped with an opening at the point of the V being one foot or more out into the water directly in front of the castor mound. This opening is then guarded with a snare. Beaver like the security of the water so by having the snare in the water instead of on shore you will catch the beaver that normally won't leave the security of the water. But most importantly, by keeping this much distance between the snare and the lure the beaver will have to go into the snare to get close enough to the lure to satisfy their curiosity. Keeping the snare off the bank will also eliminate nontarget raccoons.

The snare is set with a 9 to 10 inch noose with only about 2 inches of the snare being under water. If there is a high population of muskrats or waterfowl present the snare can be lowered another inch or two to let these animals swim through without pulling the snare down. However, the higher you can keep the bottom of the noose the quicker it tightens on the beaver. This eliminates the bulk of pulled snares by beaver as well as leg or tail catches.

During rainy weather the lure is placed in open plastic containers or covered with a 4x4 inch sheet of plastic and incorporated into the castor mound. This prevents the lure from being diluted or being washed away. However, most of the time a dead stick is used to collect an amount of lure about equal to the size of a honey bee and is simply placed on the castor mound. I might also mention rainy and windy nights are generally not as productive as "fair weather" nights. I believe the beaver's activity is somewhat reduced during bad weather and they are also more hesitant in working lured sets. The sets are relured after every catch, and if the lure was not covered, they are relured after every rain. During the hot summer months lure is added about every third day, if still needed.

For lure I prefer dried, ground castor with enough glycerine added to form a paste. As a backup lure I use ground castor with anise oil and cottonwood bud oil as additives. I add 1/2 of a tablespoon of each of the oils to an equivalent of two baby food jars full of castor and again add glycerine to form a paste. Either lure works well all year with the castor and oils mixture showing a significantly higher catch rate on a set that has already taken beaver over reluring with straight castor. During the hot summer months beaver lose some of their curiosity to lures and beaten up 2 year old beaver may shy completely away from a castor based lure.

Bait sets for beaver are most productive in early spring and again in late fall. However, this set seems to provide more interest to younger beaver, and is usually not productive on any beaver during the summer months. If there is evidence of trees being currently used for food during the summer the set will work, otherwise assume the beaver are feeding on aquatic vegetation. For the bait set, as with the castor mound set, I prefer keeping the snare in the water with only an inch or two of the snare under water. The bait is also placed in the water. This is accomplished by using naturally formed bays, or by fencing; thus allowing the beaver only one way into the bait. For bait I prefer green soft wood varieties such as cottonwood, poplar, or willow. The bait branches are from pencil-sized to wrist-sized and are placed in a floating pile with the bark removed from the ends of some of the top most branches. Corn, even when being utilized by beaver makes a poor bait due to disturbance by raccoons, muskrats, waterfowl and squirrels. Castor may be used at this set but I generally prefer not luring the bait sets as it will add variety from the castor mound set.

I also snare any narrow "bottleneck" in the stream that narrows the waterway the beaver are using. Some fencing to help guide the beaver may be necessary and again keep all but 2 inches of the snare suspended above water. This is a very productive set and no lure should be used.

Trails leading over dams are also good, especially in a multi-dam colony. I keep the snare in the water by fencing in front of the trail on the top of the dam, or most often in the trail on the bottom side of the dam where the trail meets the water as this requires less fencing.

Trails leading to the upland are also set but these trails are normally active only in the fall of the year. Again the snare is placed in the water at the head of the trail as this will avoid deer and raccoon. If the snare is used over dry ground suspend the snare about 1/4 inch off the ground and shorten the noose size down to about 8 inches.

I will usually make 6 to 8 snare sets per colony using a combination of the sets I have mentioned. Like other trapping, best results come from a variety and/or variation of sets. It is helpful to get as many beaver as possible in the first two nights before they get shy and/or lose interest in the lure.

If beaver lose interest in the lures a hole may be punched in the dam and guarded with a leghold. Keeping the hole small, about 6 inches wide and 3 inches deep, is enough to get the beaver's interest but yet keeps the beaver centered on the set in their attempt to repair the dam. I place the trap for a front foot catch so the trap is placed about 2 inches off center and no more than 3 inches under water. For animal damage control work where the entire colony must be removed the trap placement for the hind foot catch can be too variable due to the various sizes of the beaver. By September the young of the year are assisting with dam repair and any trap set for a hind foot catch on an adult will miss these smaller beaver. Another set for lure shy beaver is opening the dam and placing some dead branches on the bank a few yards upstream from the dam and guard these branches with a snare or leghold. The beaver will often times attempt to use these branches for repairing the dam.

In summary, the methods as mentioned are the methods I have used during my 14 1/2 years of animal damage control work. It is my wish with this paper to share the methods that work for me in hopes some will be applicable for you. The more methods that are available to, and used by the individuals responsible for animal damage complaint work the more efficient we will be in alleviating the problems that have been created by either man or animal.

Consider Using Electric Powered Fences for Controlling Animal Damage[1]

Robert E. Steger[2]

The use of electronics in animal damage control is not new. The use of amplified frequencies or sound has been widely used for controlling insects, rats, and other kinds of animals. Recent innovations for uses of electric powered fences are being recognized. Animals heretofore managed by expensive predacides or physical barriers are being managed with electric powered barriers. For example, caterpillars are being economically managed in New Zealand with the use of one electrical wire slightly above ground level. This application is being made possible because electric powered fences are 1) economical; 2)effective; 3) provide flexibility; and 4) are relatively easy to install.

An economic comparison of electrical powered fence to conventional fencing reveals that the electrical fence is only one-third to one-half the cost of the conventional kind. Both labor and material requirements are reduced.

In regards to efficiency, the electrical powered fence is more efficient than conventional fencing for some animals. Animals such as coyotes, buffalo, elk, moose and others may be only partially controlled by conventional fencing and may even find a challenge in tearing it up. Whereas, these same animals become very afraid of electrical fences.

Specially designed structures such as two parallel fences of a few wires on each (one or two) can restrain deer from damaging high-value crops. A slight deviation of this, the fence constructed on an angle (leaning) with the ground has been effective in controlling some animals, especially those capable of jumping.

The modification of a conventional fence with electrical powered attachments can often increase the effectiveness of an existing conventional structure. The control of coyote predation has been shown to be most effective in both Texas and Arizona studies by adding electrical wires, one slightly above ground level offsetting the conventional net wire fence and one near the top of the fence.

Flexibility is an added feature of electrical fencing. The fencing components can usually be salvaged with some ease if one decides to change the fencing arrangement or design, especially if this is included in the plan at the onset.

The ease of construction is another feature of electrical powered fencing. Most people can construct these fences following some instructions. While bracing is a critical part of the fencing design, it requires almost as much of a structure as conventional fencing. A new bracing assembly is available that is engineered to give a strong, professional-appearing brace or corner. Complete, step-by-step instructions are included to explain how to build these braces.

Ease of construction may be a relative term, however. There are some places that are remote and sufficiently rugged that this may be the only feasible way to construct a fence.

Many new ideas are being implemented into features for electrical fencing as more technology is applied. Some specific features include:

1) The application of voltage and amperage capabilities of energizers to the corresponding requirements of the animal. The early day American-made energizers were low amperage (usually less than 1 amp) and produced approximately 2,000 volts or less. Also, the energy was dissipated when an animal touched the fence. Hence, the animals tended to lunge into the fence and tear up the structure. The New Zealand type of energizers produce a pulsating current (approximately 1 per second). The voltage and amperage on the larger units that are commonly used for wildlife are relatively high (up to 100+ amps) with an operating voltage of 4,000 to 6,000 volts. The length of pulse is short enough to give a health safety factor when delivering a tremendous charge.

Cattle, horses, and swine have relatively low tolerances for electrical shock and can be controlled with approximately 2,000 volts. Sheep and goats require 3,000 or more volts. Deer and elk have hollow hair to provide some insulating effect and usually require 4,000 volts or more for dependable control. Coyotes are quite sensitive to electricity, but often require the higher voltage range of 4,000 volts or more to discourage their

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[1]Paper presented at the Wildlife Damage Control Workshop in Rapid City, South Dakota, April 28-29, 1987.

[2]Robert E. Steger, Ph.D., Public Relations, Twin Mountain Supply Co., Inc., San Angelo, Texas.

desires for a lamb dinner. Not only are these higher voltages required, but it must be delivered with adequate amperage to assure this maximum delivery under all conditions and at all times.

2) Assurance that the energizer is working at top performance at all times has been a problem in the past. Proper and adequate grounding (earthing) was a difficult thing to determine. Also, shorting of the energized wire to an unintentional ground was also a problem. The new PEL Series 5 energizers have done much to reduce these problems. They are equipped with lights that indicate inadequate grounding or shorts on the fence. This self-monitoring allows one to check the energizer to determine if the fence is working properly.

The application of round fiberglass rod posts with holes drilled through the post offer the most trouble-free fence possible. These durable posts do not shatter when being driven and a rock is encountered. Nor do they become brittle over time, heat or extreme cold, but they are self-insulating. Thus the wires will not be knocked out of insulators and cannot be shorted due to touching a post that may ground it.

3) Animal behavioral characteristics are being studied to help in reducing the amount of barrier needed to control animals. One wire, at a 10" height is adequate to control white-tailed deer movements into seeded or otherwise treated areas, for example. No doubt other animals have critical zones that can be capitalized upon.

If the resource manager can determine the cause of why animals cross a fence and may help in the application of the fencing need. Animals usually cross fences to 1) obtain something to eat or drink, or 2) to join other animals.

One must remember that the electrical powered fence is a mental barrier rather than a physical barrier. Some physical barrier must be applied for jumping animals. Thus, the fence must be in constant operating order to be effective. Many animals such as cattle and deer can tell if the fence is working, even without actually touching the fence.

Fencing Methods To Control Big Game Damage to Stored Crops in Wyoming[1]

John F. Schneidmiller[2]

Abstract.--Fighting damage to stored crops by big game animals is both costly and time consuming. Fencing methods are the most suitable means to prevent big game damage to stored crops. Experimentation in fencing methods is ongoing to find the best and most cost effective solution to this problem.

Ever since the beginning of time, when early man figured out how to put a seed in the ground to produce food, he realized that more could be produced than could actually be used. At that time, if he could store these crops, they would be available to him for future use. These stored crops, however, were made available to all sorts of critters. Among these critters are what we now call the big game animals. Mule deer (Odocoileus hemionus), white-tailed deer (Odocoileus virginianus), pronghorn antelope (Antilocapra americana), elk (Cervus canadensis), and moose (Alces alces) are the big game animals which I will be referring to in this presentation.

Private landowners seem willing to take care of most of the problems associated with ranching. However, many of these landowners feel they should not be responsible for depredation by big game animals that are managed and protected by a state agency (Strickland 1976). Wyoming, as is true with numerous other states, is responsible for these damages caused by big game animals. Monetary compensation to the landowner is for the value of standing or stored crops as required by Wyoming law. Almost all damage in Wyoming occurs on private or leased lands. Big game damage to crops and compensation to landowners are sometimes emotional problems between landowners and the hunting public.

The State of Wyoming is divided into seven game supervisor districts. Within these seven supervisor districts are forty-six game warden districts. In Wyoming, the Game Warden is charged with the responsibility for wildlife damage within his warden district. In each game supervisor district, there is one Damage Control Warden who is responsible for the storage of equipment and supplies and some of the actual damage prevention and investigation, and Department payment recommendation of landowner damage claims. Each game supervisor district has a budget for purchasing damage prevention materials and equipment. This budget is approved by the Wyoming Game and Fish Commission. Materials and equipment are stored in each Game Warden District as well as at a central location within the Game Supervisor District. Materials and equipment are dispersed from these locations to landowners having big game damage problems.

There are many different methods of controlling damage to stored crops. The most effective means of protecting stored crops is our physical presence at the stackyards. The second most effective method of protecting stored crops is various types of barriers, such as fences. We have experimented with many different barriers and each will be explored within this paper.

THE LAW

Under Wyoming law, it is the responsibility of the Game and Fish Department to investigate damage complaints and to recommend to the Commission fair and appropriate compensation to the landowner. It is at the sole discretion of the Commission whether or not to allow or reject any damage claim or portion thereof. Wyoming Statute 23-1-901 (Wyoming Game and Fish Department 1985) describes the action the landowner and the Department must take when damage has occurred:

> "Any landowner, lessee or agent whose property is being damaged by any of the big game animals of this state shall not later than fifteen (15) days after the damage is discovered by the owner of the property or the representative of the owner, report the damage to the nearest game warden, damage control warden, supervisor or commission member.

[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop, in Rapid City, South Dakota, April 28-30, 1987.

[2]John F. Schneidmiller is Damage Control Warden, Game Division Supervisory District III, Wyoming Game and Fish Department, Buffalo, Wyoming.

(The landowner must) "...present a verified claim for the damages to the Wyoming Game and Fish Department not later than sixty (60) days after the damage or last item of damage is discovered. The claim shall specify the damage and amount claimed....

The department shall consider the claims based upon a description of the livestock damaged or killed by a trophy game animal, the damaged land, growing cultivated crops, stored crops, seed crops, improvements and extraordinary damage to grass. Claims shall be investigated by the department and rejected or allowed within ninety (90) days after submission....No award shall be allowed to any landowner who has not permitted hunting on his property during the authorized hunting seasons...."

In general, the landowner, in a timely manner, reports the damage to the Department. Department personnel meet with the landowner, investigate the damage, and make recommendations as to the level of compensation, if any. The Commission then acts upon this recommendation and level of compensation.

COST

It is no secret that the present economic trends of today have severely depressed the agricultural community. As a result, landowners are less tolerant of big game damage and recognize the potential of receiving compensation for crop damage as making up some of their losses.

Damage control costs have equally increased for the Department. We now furnish materials to prevent or discourage damage to stored crops by big game, and the landowner furnishes the labor for the construction of stackyards. Cooperation between landowners and the Department has and is improving.

Costs are broken down into three general categories:

Landowner Coupons

The Landowner coupon payment program was established by the Wyoming Legislature to compensate the landowner for forage consumed by deer and antelope legally harvested on deeded land. This incentive program was initiated to stimulate harvest on private land where damage was occurring and is a valuable management tool. Payments from 1976 through 1979 were made at $5.00 per coupon. In 1980, an increase of $3.00 per coupon was implemented by legislative action. No compensation is made for those animals harvested on state or federal land controlled by these landowners nor is compensation made for big game animals other than deer and antelope. Table 1 shows the 10-year trend, 1976-1985, of the number of deer and antelope landowner coupons redeemed, the percentages of coupons redeemed by landowners and the total dollar amount paid out by the Department (Wy. Game and Fish Department 1976 through 1985).

Damage Claims

As the stress of hard economic times filter into the agricultural community, ranchers and farmers understandably start looking for additional sources of income. Although they see the game animal as both a source of food and, as a fringe benefit of living with the animals, they also view them as an added source of revenue. As landowners become familiar with the process of compensation for big game damage, they also become more aware these added revenues are not difficult to obtain. A feeling of complacency can set in and for this reason, a strict damage investigation process has been implemented by the Department. However, in the majority of cases, this lengthy and complicated process is not completed as the landowner and Department personnel reach an agreement on the amount of compensation to be paid, and the Commission agrees.

Table 1.--1976-1985 Deer and Antelope Landowner Coupons Redeemed, Percentage of Coupons Redeemed, and Total Dollar Amount Paid by Department

YEAR	DEER COUPONS	% DEER COUPONS REDEEMED	ANTELOPE	% ANTELOPE COUPONS REDEEMED	TOTAL # COUPONS REDEEMED	TOTAL EXPEND. TO DEPT.
1976	43,891	40%	39,216	60%	83,107	$415,535
1977	38,914	36%	35,527	55%	74,441	$372,205
1978	34,864	31%	33,739	52%	68,603	$343,015
1979	30,551	27%	24,717	48%	55,268	$276,340
1980	30,888	28%	24,801	43%	55,689	$445,512
1981	34,247	29%	34,888	51%	69,135	$553,080
1982	38,066	25%	42,696	55%	80,762	$646,096
1983	42,118	25%	54,241	59%	96,359	$770,072
1984	37,692	30%	46,747	41%	84,439	$675,512
1985	34,833	29%	39,169	40%	74,002	$592,016

The number of damage claims submitted each year varies greatly depending upon the severity of the winter. Figure 1 shows the total number of damage claims submitted to the Department, and the total number of damage claims paid by the Department for big game animal damage to stored crops. This figure shows a 10 year trend of actual damage claims submitted to the Department, and the number of claims paid for big game damage to stored crops. Note the decline from 1979 when the implementation of giving out the damage materials was started. An increase is noted in 1984 when a very severe winter set in, and afterwards a downward trend is again noted. During this 10 year period, the difference between total claims submitted to the number of claims paid goes from a low of 31% to a high of 53% (Wy. Game and Fish Department 1977 through 1986).

Figure 2 shows a 10 year graph illustrating the total dollar amount of damage claims submitted to the Department and the dollar amount paid out by the Department solely for damage by big game animals to stored crops. Again a downward trend is noted from 1979 when materials were made available to landowners up to the very severe winter of 1984 when the upward trend is once again noted. The dollar amounts paid by the Department due to damage by big game animals to stored crops goes from a low of $12,322.00 in 1979 to a high of $153,780.00 in 1984. The differences in amounts by percentages stretch from a low of 15% in 1981 and 1982 to a high of 71% in 1984 (Wy. Game and Fish Department 1977 through 1986).

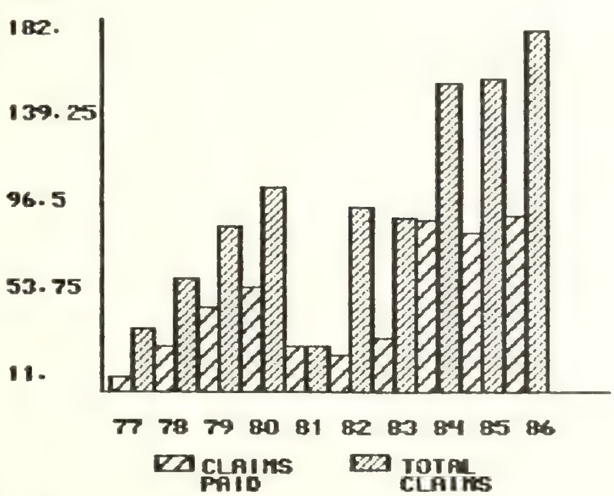

Figure 1.--10 Year trend of all damage claims submitted vs. damage claims paid for big game animals damage to stored crops.

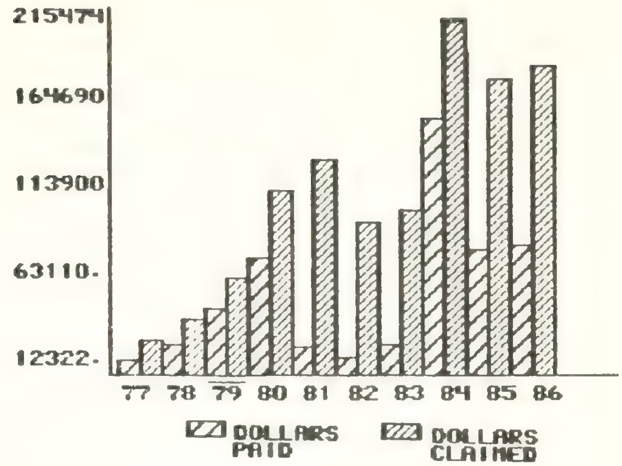

Figure 2.--10 Year trend of total dollar amount claimed vs. dollar amount paid due to damages by big game animals to stored crops.

Damage Material

As previously stated, the Department is responsible for preventing or minimizing the extent of damage, to assist landowners, and minimize payments for damage. Each of the seven game supervisor districts manages its own budget to provide adequate material for alleviating damage. Under the direction of the local game supervisor, through the damage control warden, traditional damage control methods and some experimentation are ongoing activities within each district.

The various methods currently used to curb damage to stored crops are: 1) barbed wire; 2) electric fencing; 3) remesh fencing; 4) woven wire; 5) reinforced plastic; 6) 6' wood cribbing; 7) tensar radar fencing; and 8) 8' wood cribbing. Table 2 shows the different types of fencing material provided and the approximate cost per linear foot.

Barbed wire fencing is the least effective method of preventing damage, as most big game are very adept at jumping over these barriers or simply going through them. It is, however, the least expensive method. Barbed wire exclosures can be made into good permanent type stackyards by elevating the wire to a height of six feet to seven feet. Wire strands should be spaced at about every four inches. Ten foot posts are a requirement for this type of exclosure. Constant care is a must for this exclosure as animals will keep jumping into the wire and damaging it. Once animals have created a hole through the fence at a certain point, it can then be expanded. The animals have a way of finding this entry, thus leaving the exclosure very vulnerable.

Electric fencing is about as effective as barbed wire in that most big game animals simply jump over the barrier. It is most effective in preventing antelope damage as antelope prefer not to jump, but rather attempt to go through or under fences. Two to four electrically charged strands can be incorporated into the exclosure to keep animals from nosing between the strands and then jumping through, gaining entry to the stored crop inside.

Remesh fencing in the six foot height is very effective with most big game animals as they will not attempt to jump over this. We have in the past used 5' remesh, however, with deep snow conditions animals will more readily attempt to jump into or over this fence. The added one foot of height seems to be the solution to this problem. Some type of posts must be used with this protection. It can be used for permanent or temporary stackyards depending upon the need. The main drawback for remesh wire is that it is very difficult to handle.

Woven wire used in permanent stackyards is the method we have found to provide the best protection on a long term basis, for all types of crops from big game damage. Permanent stackyards are often an improvement to the landowners property, a benefit to his operation and effective in preventing stored crop damage. They do, however, require considerable labor by the landowner to build. Thirty-nine inch woven wire may be substituted for 47 inch, as the need dictates. The wire is installed in combination with barbed wire. One strand of barbed wire is then placed six inches from the ground, then six inches above this is the 47 inch or 39 inch woven wire, followed at six inch intervals by three to four more strands of barbed wire, to a total of six and a half or seven feet in height. Ten foot posts are required for this exclosure.

Reinforced Plastic is a temporary type of crop protection and is very easy to install. It is simply a 10 foot wide sheet of polyurethane plastic, 100 feet long, stretched over the desired crop and anchored down every 3-4 feet for the length of plastic sheeting. However, it is a very expensive material to use.

Wood cribbing may be both a temporary and permanent type of fencing and has been used by the Department for longer than any other type of fencing. It is constructed with 1"x4"x6' boards for deer fence and 1"x4"x8'lengths for elk fencing. Four strands of 11 1/2 ga. galvanized wire are used to tie the boards together. A fencing machine is required to keep the proper distance between boards and to twist the wire around each board. The fencing can be made in any desired length, however experience has proven that 15 foot lengths are the easiest to determine quantity needed, handling of that material, and ease of installation. It should be constructed in advance at a slack period when a crew can be assembled to do the work. A rather large area is also required to store the finished product as they are large and bulky. When installing, this fencing is considered difficult to handle. If cared for properly by the landowner, these panels will last several seasons.

Tensar Radar Fencing is a plastic type fence protection. We are experimenting with this material to evaluate its effectiveness and cost for big game damage control. It is both temporary and permanent in nature and very easy to install. At the present time, only two of these stackyards are in use in Wyoming. One is 7 feet in height and the other utilizes two 4 foot lengths laced together. Posts are needed with this protection with the plastic fencing being stapled right to the posts. At first, some concern was noted as to the extreme low temperatures experienced in Wyoming. However reports received from field personnel have stated that no trouble has been experienced at -25 degrees below zero. It is considered very expensive to install.

Table 2 shows the different types of fencing and how they compare as to size, cost, weight, ease of handling, support needed, temporary or permanent type exclosure and the cost per linear foot.

CONCLUSION

It is not our intention to dictate to each and every landowner what type of material is to be used by him in the protection of his stored crops. Each situation is different and must be handled on a case by case basis. However, the quest for finding economical and logical solutions to minimize damage is an ongoing challenge. Cooperation is a must between landowners and Department employees if successful solutions are to be reached.

Damage prevention and compensation for damage by big game is very expensive. These expenses come under three general headings of: 1) damage materials (which are now provided by the Department with very good results. However, due to budgetary constraints, distributing these materials is a slow process), 2) landowner coupon payment program (a valuable management tool for the Department and a good incentive program for the landowner to harvest surplus game animals), and 3) damage claims (claims filed against the Department correspond directly to the severity of winter conditions).

Table 2.--1986 Fencing Costs

FENCING	SIZE	COST	WEIGHT	HANDLING	EXTRA SUPPORT	TEMPORARY OR PERMANENT	COST/ LINEAR FT.
Barbed Wire	1300'	$30/ roll	60 lb./ roll	Medium	Posts needed	Permanent	$.02/ft.
Electric Fence	660'	$36/ roll	15 lb./ roll	Easy	Posts needed	Temporary	$.19/ft.*
Remesh	6'x150'	$54/ roll	250 lb./ roll	Difficult	Posts needed	Both	$.36/ft.
Woven Wire	39"x330'	$73/ roll	200 lb./ roll	Difficult	Posts needed	Permanent	$.44/ft. 6 1/2' high
Reinforced Plastic	10'x100'	$130/ sheet	30 lb./ sheet	Quick & easy	None	Temporary	$1.30/ft.
6' Wood Cribbing	6'x15'	$11 w/o labor $22 w labor	250 lb.	Difficult	Posts may be needed	Both	$1.47/ft. w/labor
Tensar Radar Fence	7'x164'	$285/ roll	100 lb./ roll	Easy & quick	Posts may be needed	Both	$1.74/ft.
8' Wood Cribbing	8'x12'	$14 w/o labor $28 w/labor	250 lb.	Difficult	Posts may be needed	Both	$2.33/ft. w/labor

*Includes insulators and charger cost
SOURCE: Demaree, John R. 1986. Personal correspondence. Wy. Game and Fish Department. Laramie.

There is little that can be done to alter the amount paid out by the Department for landowner coupons. However, ongoing experimentations as to the various and best solutions to stop depredation to stored crops can and will have a direct effect on the amount of actual dollars paid out by the Department on damage claims. It is the intention of the Wyoming Game and Fish Department to seek out and find solutions to the damage problems created by big game animals through fencing methods. With the help and cooperation from private landowners, we will find solutions to the problems of damage.

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Kansas Wildlife Damage Reporting System[1]

Bart L. Hettenbach[2]

Abstract.--In the past several years Kansas State University's Extension Wildlife Damage Control Program and the Kansas Fish and Game agency have developed a cooperative program for reporting wildlife damage complaints. The paper will present some data collected, describe the usefulness of this data and provide some data interpretation.

INTRODUCTION

The purpose of this paper is to describe the important information that can be obtained from a simple cooperative reporting system conducted between state agencies.

In the past several years Kansas State University's Extension Wildlife Damage Control program and the Kansas Fish and Game agency have developed such a program. The standard reporting form first designed has been further improved over the past few years (fig. 1). The standardized reporting form provides us with information such as the complainant's name, county, description of the problem, economic loss, recommended actions, and whether the problem was solved. This form is then filled out and returned to our office monthly by Wildlife Conservation Officers and County Extension Agents. Wildlife damage control volunteers receive a newsletter six times a year and report on a yearly basis to our office. There are approximately 200 wildlife damage control volunteers in Kansas. There are 105 County Agricultural Agents, and 60 Fish and Game personnel who participate in sending wildlife damage control reports.

COUNTY____________ WILDLIFE DAMAGE COMPLAINT RECORD Month________, 19____

Complainants Name	County	DESCRIBE PROBLEM: Species and numbers of wildlife involved, crop or item damaged, degree of damage (estimated), contributing factors, etc.	*Economic Loss 1	2	3	Recommended Actions	Was Problem Solved?

Return to: F. Robert Henderson, Extension Wildlife Damage Control, Room 113, Umberger Hall, Kansas State University, Manhattan, KS 66506

*Economic Loss Rate: (Check one) 1. Nuisance; 2. $1-300; 3. $300 or more.

Cooperative Extension Service, Kansas State University, Manhattan

All educational programs and materials available without discrimination on the basis of race, color, national origin, sex, or handicap.

Figure 1.--Standardized reporting form used.

[1] Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop. South Dakota School of Mines, Rapid City, April 28-30, 1987.

[2] Bart L. Hettenbach is a Senior in Wildlife Biology, Kansas State University, Manhattan, Kansas.

METHODS

These data are based on reports received and kept by Kansas State University in the Extension Wildlife Damage Control office. Once each month, the agency, county, month, species, and economic loss are entered on a Zenith computer into a DBase II file for storage on a hard disk and back-up floppy disk. After this information is entered into the computer, it can be utilized to write informative reports. Reporting individuals from the two agencies report each month even if they receive no requests regarding wildlife damage control.

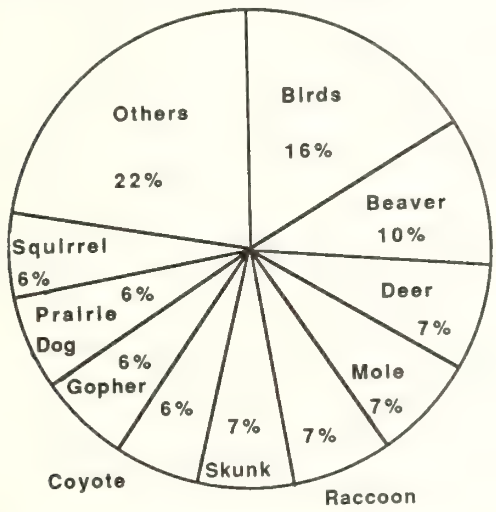

Figure 2.--This pie chart indicates the percent of damage caused by the top 10 individual species in Kansas for 1986.

RESULTS

Figure 2 shows the 1986 statewide damage for Kansas and indicates which species caused the most damage. As figure 3 shows, rodents and predators caused the greatest economic loss. In 1986, of the 1,959 reports, 63% were nuisance, 31% were between $1 and $300 damage, and 6% were estimated at over $300 damage.

The data collected also show where damage is occurring in the state. Kansas is divided into five administrative Extension areas, as shown in figure 4.

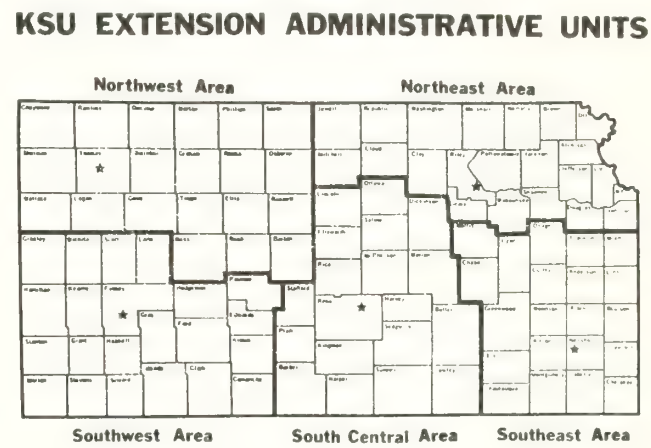

Figure 4.--Kansas State University Extension administrative units.

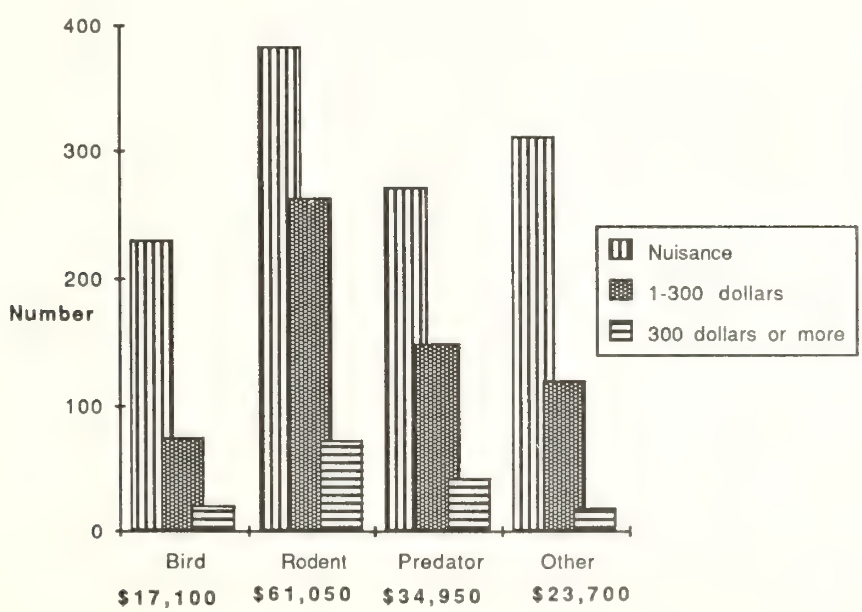

Figure 3.--Estimated dollars of damage which occurred in 1986.

In figure 5, beaver damage complaints have been broken down into the five KSU Extension administrative units.

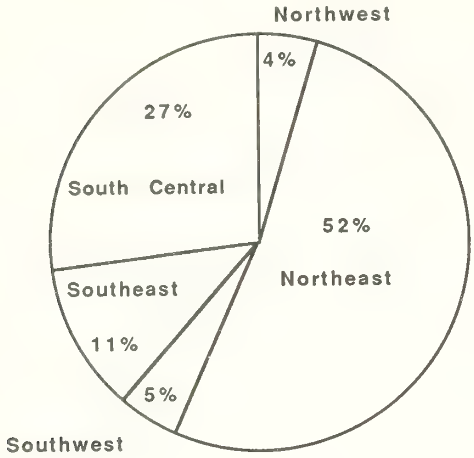

Figure 5.--Beaver damage for 1986, divided into KSU Extension administrative units.

A few problems do exist with our reporting system. All cooperators do not report on time, and some neglect to report at all. The ones that do report regularly sometimes do not include all the information requested. The dollar estimates may be low, as each respondent estimates these subjectively. The most common problem found with these reports is the lack of follow-up to determine if the problem was solved. Often Agency personnel assume the problem was solved since the complainant did not call back. We have checked a randomly chosen sample, and indications are that over 80% of the problems are reduced, if not solved.

SUMMARY

The information obtained from these reporting forms indicates where in the state help is needed in educating people on the best methods of control. This kind of data also shows: (1) times of the year problems are most likely to occur; (2) changes from year to year; and (3) for research, the need for improving old control methods or finding new ones. These kinds of data are helpful to explain the extent of wildlife damage in Kansas and to help reduce wildlife conflicts with people. We realize that not all losses or complaints with wildlife are reported. However, this standardized method of reporting does indicate trends and gives a good idea as to the kinds of wildlife problems and our ability to solve or reduce these problems in Kansas.

Results of a Bird Damage Survey of Kansas Feedlots[1]

Charles Lee[2]

Abstract.--A mail survey was conducted in the Fall of 1986 of 196 licensed Kansas feedlots to get a better idea of the extent as well as kinds of wildlife damage they experience. The results of this survey are being used in designing a research project to help feedlot operators cope with bird damage.

INTRODUCTION

Kansas currently ranks third behind Texas and Nebraska with annual fed cattle marketing exceeding 4 million cattle (Laudert 1987).

The Kansas feedlot industry is large, diverse and rapidly growing. Unfortunately, feedlots with open bunks with continuously available feed also provide starlings (Sturnus vulgaris) and several species of blackbirds (Icteridae) with an abundance of winter food. Feedlot operators report large populations of starlings from October through February. Starlings consume livestock rations, contaminate feed and water and may spread disease.

There is a need for effective and acceptable methods for dealing with these large flocks of birds so that feedlots can stay competitive with areas that do not experience bird problems.

METHODS

The Kansas Cooperative Extension Service sent a questionnaire to 196 licensed feedlots in Kansas in the Fall of 1986. Feedlots surveyed included cattle, sheep and hog operations with a one-time capacity of at least 1000 head. Feedlot operators were asked 10 questions about bird damage problems they experienced. Most questions required single, short answers, but too many allowed longer, more involved responses. This survey design has too many variables to allow statistical analysis. The results of this survey provide descriptions of current bird problems experienced by Kansas feedlots. Eighty questionnaires were returned.

RESULTS

Locations Involved

Feedlots ranging in size from 2000 to 100,000 head marketed 96.4% of the 4.2 million cattle finished in Kansas in 1986 (Laudert 1987). The 80 feedlots that responded to this survey were primarily in the southwestern and south-central sections of Kansas (fig. 1). The capacity of the feedlots responding to this survey ranged in size from 1,000 to 100,000 head (fig. 2). Bird damage is a problem for large and small feedlots. Problems with birds were reported at 83.5% of the feedlots that responded to this survey.

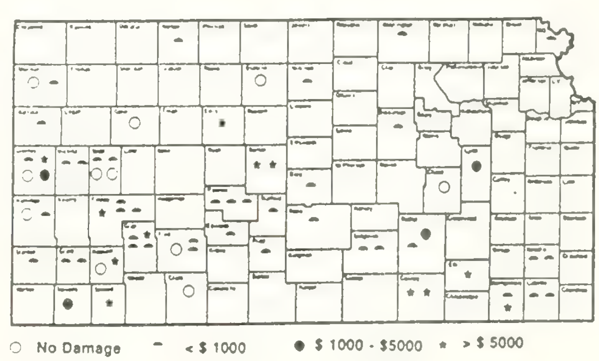

Figure 1.--Locations of feedlots responding to 1986 survey and amount of damage reported.

[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop. South Dakota School of Mines, Rapid City, April 28-30, 1987.

[2]Charles Lee is Extension Assistant, Cooperative Extension Service, Kansas State University, Manhattan, Kansas.

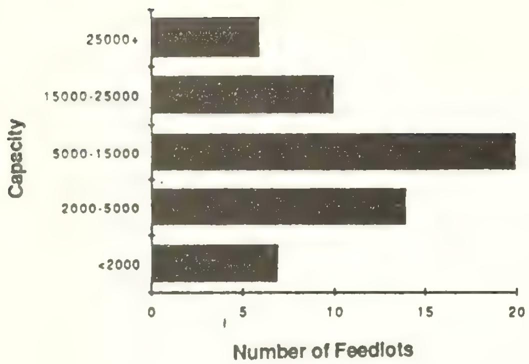

Figure 2.--Capacity of feedlots in Kansas responding to 1986 bird damage survey.

Species Involved

Approximately 86% of the respondants who had bird problems reportedly had starling problems. Other problem birds reported were blackbird, sparrow (Passer domesticus) and pigeon (Columba livia) (fig. 3). About 41% experienced problems during the winter, and 35% had problems in the fall. Twenty feedlots reported bird problems the year around.

Specific Location of Bird Damage

Of the feedlots responding, 44% had bird problems both inside and outside buildings. Thirty-eight percent had problems outside with only 3.8% reporting problems inside buildings.

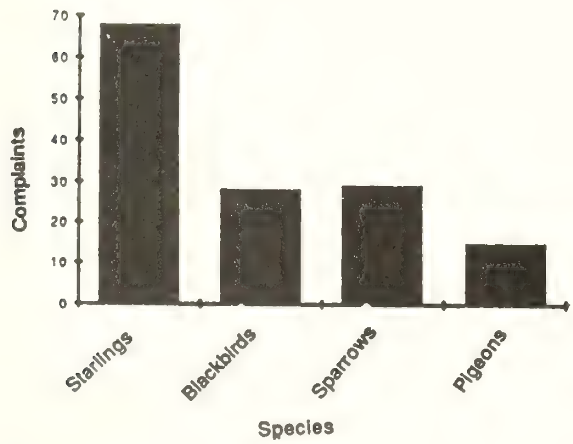

Figure 3.--Species involved in feedlot damage.

Major Problem Reported

Most feedlots (64%) cited feed loss as the major problem. This was actual feed consumption and feed that was contaminated that was removed. Over 21% were concerned about the birds spreading disease. Starlings have been associated with 17 diseases (Weber 1979). More information is needed that definitely links birds with the spread of disease in livestock. Other problems included building damage and the general mess associated with bird droppings. Some feedlots report having men clean livestock waterers daily to remove accumulated bird droppings.

Bird Activity in Years

Most of the feedlots report bird problems every year, with 41% reporting that some years were worse than others.

Control Methods

Control methods that have been tried include poison bait, shooting, frightening devices and poison perches (fig. 4). Approximately 66% said control methods were not always effective in reducing the amount of damage due to birds.

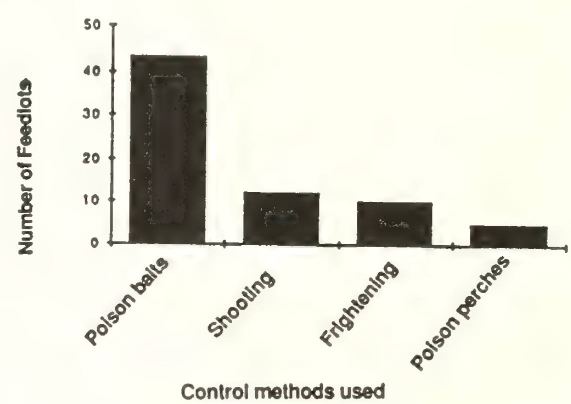

Figure 4.--Methods used by Kansas feedlots to control birds.

Estimated Dollar Amount

Only 20 feedlots reported a dollar amount on the cost of bird problems. This total loss reported was $246,800. Many feedlots reported economic loss but did not know how to estimate this loss. The average loss incurred by the feedlots responding was $12,340. The average expense in trying to control bird problems

of those feedlots answering this question was $1,873. More feedlots knew the expense of control efforts than the economic loss they incurred.

Other Wildlife Problems

Eighty-seven percent of the feedlots reported other kinds of wild animal problems. In order of importance, they were rats and mice, raccoons, coyotes, badgers and skunks.

As the feedlot industry becomes more stressed, operators are looking for ways to maximize productivity. A reliable and accurate means of measuring damage, with training in how to apply the methods and justify current control technologies is needed.

We are not going to say to anyone that we are going to solve the bird problems that feedlot operators are experiencing. We should be able to quantify damage loss and determine why current technology is not effective in reducing losses due to birds 66% of the time.

We intend to conduct research and Extension demonstrations during 1987 and 1988 on one promising idea to reduce or even prevent the loss due to birds. We will test the use of live Harris hawks (Parabuteo unicinctus) to scare off birds. The Air Force uses falcons to kill and scare birds away from airports in Britain and Canada (Blokpoel 1976). This method would be acceptable to environmentalists and may provide employment for some of our citizens.

Another idea that will be researched is the control of starlings by electrocution. This idea has been suggested in the past (Jacob 1965). The behavior of starlings liking to land on wires would seem to make this idea feasible.

We also plan to continue the evaluation of dimethyl anthranilate as a nontoxic starling repellant that can be mixed in the cattle ration (Mason 1983).

Financial support for these studies is being provided by the Kansas Livestock Association Cattle Feeders Council and individual feedlot operators. Research and Extension work will be guided by Kansas State University Department of Animal Sciences and Industry in the College of Agriculture.

SUMMARY

The response from the feedlot industry in Kansas indicates a need for effective control methods for bird problems around feedlots. The wildlife damage control Extension staff will evaluate current control methods and test some new ideas to prevent or reduce the economic loss associated with birds. The resulting recommendations will be written in the form of a manual for feedlot operators relating to animal damage control at feedlots. The project will be completed in the fall of 1988.

I would appreciate any suggestions or comments on this proposed research.

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Control Methods for Objectional Roosts of Purple Martins[1]

Albert E. Bivings, IV[2]

Abstract.--Multi-thousand bird roosts of Purple Martins (Progne subis) occasionally form in the South during the early summer (June-July). Nightly depositions of fecal material create considerable nuisance and potential health problems. Since they are federally protected migratory birds and have legions of bird-lovers trying to increase their populations, lethal controls are unlikely to be popular or even permitted. Control techniques including plastic netting (partial or complete exclusion), active scaring and modification of building schedules are discussed and evaluated. Plastic netting was observed to be the most successful long-term solution.

INTRODUCTION

Purple Martins are an extremely popular member of the swallow family. They are a common summer breeding bird throughout the South arriving often in early February (Farrand 1983). Nesting activity runs from March through July. After nesting, they begin to congregate in roosts as early as late May through as late as mid-August. Large roosts of up to 6,000-10,000 birds have been reported in June and July (James and Neal 1986). After this peak, they begin to migrate south toward their wintering grounds in Brazil (Farrand 1983).

These large aggregations of birds are often attracted to lighted structures with a quantity of sheltered small diameter rods for perching. The lights seem to allow them to feed both on a concentration of insects and for a few minutes longer than at other sites before they go to roost. The problem comes from the nightly accumulation of fecal material under these roosts which causes nuisance, morale, safety, and potential health problems (Weber 1975). Whether or not lethal control might be appropriate is a moot question. Due to the vast number of bird-lovers who admire Purple Martins and their reputation (regardless of how appropriate) as effective mosquito/insect control agents, obtaining permits for any lethal control is highly unlikely in the current political environment. Thus, the only alternatives are to scare them or exclude them from the buildings.

The purpose of this paper is to describe and discuss both effective and ineffective control methods for Purple Martins. Thanks are due to Messrs. M. Hoy and T. Booth for their helpful critique of this manuscript and Mrs. G. Hiryak for her assistance in the preparation.

INEFFECTIVE CONTROL MEASURES

A plethora of advertising is currently available for predator decoys, ultrasonics, and flashing lights. While a few have experienced some success, these devices generally are ineffective. Birds have essentially the same hearing range as man and ultrasonics have yet to be demonstrated to be effective on birds. Predator models (snakes, owls, etc.) that are static usually only work for a day or two if at all. Some animated models may be somewhat more effective. The same applies to loud music, rotating beacons, shiny objects, etc. Will (1985) provides a more detailed discussion of these items.

EFFECTIVE CONTROL MEASURES

Not all control measures can be expected to work or be feasible for every situation. Control methods can basically be categorized as schedule changes, exclosures, or scaring.

Schedule Changes

Some benefit can often be obtained from modification of work/building schedules. One of the simplest, yet least often tried techniques is to turn off the interior/exterior lights for the first hour after dark. While this may not move an established roost, it may well keep the birds from returning in subsequent years if begun before the birds begin to roost at a given location. Closing

[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop. [U.S. Forest Service, Rocky Mountain Forest and Range Exp. Stn., Rapid City, South Dakota, April 28-30, 1987].

[2]Albert E. Bivings is Wildlife Biologist for U.S.D.A.-A.P.H.I.S., Animal Damage Control, Stuttgart, AR.

all possible entrance doors and windows will also help make the location less attractive to new arrivals.

Scaring

Purple Martins respond well to traditional bird scaring devices. The combination of pyrotechnics, propane cannons and bio-acoustics using red-wing blackbird or gull tapes described by Bivings (1985) works well on most Purple Martins. Application of water from a high pressure hose to those few that are persistent combines to make a very effective scaring program. However, scaring programs do nothing to resolve the long-term problem which is the basic attractiveness of the site to birds.

Exclusion

There are several general methods for excluding birds from an area. Those most readily available are chemical repellents, sharp pointed projections and netting.

Chemical Repellents

These devices usually come in a paste, gel, or liquid formulation and produce a tacky surface or a "hotfoot" effect. Surfaces must be cleaned prior to application of the material. The principal problem is that they lose their effectiveness when contaminated by dust, feathers, or fecal material so they are usually good for only a few months. Also, some products may melt and run off the surfaces under hot weather conditions or may be washed off if exposed to wet weather. Application of these materials is very labor intensive and all or almost all potential roosting surfaces must be covered to be completely effective. Given these handicaps, chemical repellents do offer consistent control when properly applied.

Sharp Projections

These are strips of metal with sharp pointed wire which look like a porcupine. These prevent birds from lighting on ledges covered with this material. Like chemical repellents, this material requires a great deal of labor to install. The major limitation is the great cost of the material and installation. It is simply not economically feasible for indoor sites where large areas must be protected. In areas exposed to weather, this method may be useful to protect small areas such as ledges over a major building entrance.

Netting

Probably the best long-term results have been obtained from the use of netting to exclude birds from roosting areas. Although netting is available made from cotton, nylon or monofilament materials, plastic netting is currently the most useful for this purpose. Several different strategies are available but most interfere with daily activities. The strategy which interferes with daily operation least is to attach netting under the interior supports similar to the methods described by Pratt (1983) so that the upper rafters are not accessible. If all entry holes can be sealed, this offers excellent results. Since the materials are not exposed to the weather, currently available netting will offer a minimum of 3-5 years of service without replacement. Principal limitations are the cost of installation and modifications required if the building design presents difficulties. Another strategy is to hang netting down like a curtain to close off access to the roosting areas. While this is very effective in a building with little traffic in and out, it is a considerable problem for an aircraft hangar or an open work shed or walkway which all have considerable traffic in and out. Some success has been obtained by hanging netting in the top third of the opening and attaching light weights to the bottom to reduce blowing. Since roosting birds normally only use the very top of an opening, this is a barrier to the birds, but the people can go in and out through the bottom. Another variation is 2-inch vertical plastic strips from top to bottom. These are commonly used as thermal barriers into cold storage areas, but have been effective on birds.

CONCLUSION

Architects design structures based on aesthetics or functional efficiency. Birds subsequently find unplanned uses for these structures and we must come in after the fact and try to resolve the existing problem. Plastic netting seems to offer the best and longest lasting results. As the quality of these materials improve, I expect that this option will become even more attractive. Managers will have to choose between appropriate options to decide the magnitude of the problems caused by the birds as compared to the cost and magnitude of the problems caused by the control measures. Our job must be to provide these options along with our assessment to assist the managers with their decision.

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Poster Session

A Prairie Dog Control Program on the Fort Berthold Indian Reservation

Tom Hilken
USDI Bureau of Indian Affairs
New Town, North Dakota

Evaluation of Dimethyl Anthranilate as a Bird Repellent

John L. Cummings, J. Russell Mason, and Melvyn V. Garrison
USDA, APHIS, ADC
Denver Wildlife Research Center
Denver, Colorado

F. Robert Henderson
Extension State Leader
Kansas State University
Manhattan, Kansas

Robert Timm
Nebraska Cooperative Extension Service
University of Nebraska
Lincoln, Nebraska

Exhibitors

Prairie Dog Bait Dispensers
Joe Ebert
104 E. 'A'
Valentine, NE 69201

Elston Equipment Co.
706 N. Weber
Sioux Falls, SD 57102

Hancock Trap Co.
Buffalo Gap, SD 57722

Mohr's Fencing
Merle Mohr
P.O. Box 1295
Aberdeen SD 57401

National Animal Damage Control Association
William Fitzwater
3919 Alta Monte, NE
Albuquerque, NM 87110

Reed-Joseph International Co.
P.O. Box 894
Greenville, MS 38701

South Dakota Dept. of Game, Fish & Parks
Animal Damage Control
Steve Thompson - Rattlesnakes & Trapping
Murdo, SD 57559

Twin Mountain Supply Co., Inc.
P.O. Box 2240
San Angelo, TX 76902

Tru Catch Traps, Inc.
P.O. Box 816
Belle Fourche, SD 57717

Wildlife Control-Margo Supplies Ltd.
Site 8, Box 2, RR #6
Calgary, Alberta T2M 4L5

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

United States
Department of
Agriculture

Forest Service

**Rocky Mountain
Forest and Range
Experiment Station**

Fort Collins,
Colorado 80526

**General Technical
Report RM-155**

Documentation of the National Forest System Resource Interactions Model

Tony Baltic and John Hof

Abstract

The National Forest System Resource Interactions Model is an upper level linear programming model developed to aid in the analysis of multiresource interactions for the 1989 RPA National Assessment. This report documents the development and structure of this linear programming model, emphasizing its multilevel nature and the data requirements for such an approach. The resolution of data deficiencies, a major problem in applying such a multilevel optimization approach, also is examined.

General Technical Report RM-155 April 1988

Documentation of the National Forest System Resource Interactions Model

Tony Baltic, Operations Research Analyst

and

John Hof, Principal Economist

Rocky Mountain Forest and Range Experiment Station[1]

[1]Headquarters is in Fort Collins, in cooperation with Colorado State University.

Contents

Documentation of the National Forest System Resource Interactions Model

Tony Baltic and John Hof

Information on resource interactions has been identified in the provisions of the legislation (the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) as amended by the National Forest Management Act of 1976 (NFMA)) as an essential component of national renewable resource assessments. However, estimation of resource interactions is very complex, especially when several resource outputs are involved over a large geographical area, such as the National Forest System (or just one National Forest System Region). After the completion of two national assessments, quantitative information on renewable resource interactions is still very limited. One of the major conclusions of the chapter on Multiple Resource Interactions in the 1979 Assessment (USDA Forest Service 1981) was:

> At the present time, knowledge of these interactions is limited and should be the focus of increased attention from the forestry research community. The accuracy of any modeling efforts to quantify these resource interactions will be limited by the understanding of both the biology and economics of multiresource production.

In the research needs chapter of the same Assessment, it was stated:

> Information on physical responses of forest and range land and the associated waters to management practices is still inadequate and especially so for multiresource interactions. The effort now going into describing and measuring the responses of these resources to management practices must be greatly expanded to provide the information necessary for efficient administration and management of forest and range lands.

In these discussions of resource interactions, investment and environmental impacts are explicitly included as an integral part of the analysis.

This report documents the development and structure of a National Forest System Resource Interactions Model. The model was developed to respond to the legislative provisions and assessment of research needs, and represents the present level of applicable technological development.

STRUCTURE OF THE MODEL

The multilevel resource interactions analysis utilizes upper level linear programming (LP) models to develop technically efficient regional production possibilities. Discrete management alternatives generated by the local (forest) level planning LP models (Johnson et al. 1986a, 1986b, 1986c, 1986d; Kelly et al. 1986; Kent et al. 1985; Robinson et al. 1986) are used in the upper level models as the decision variables for quantifying resource interactions. Regional level results from this analysis may be integrated into a national level renewable resource planning process. Bartlett (1974) and Wong (1980) did much of the early work in developing this approach. Hof and Pickens (1986) developed the details of this approach and tested it in a case study.

Table 1 shows an abbreviated version of the upper level model. In this example, only two forests (subscripted 1 and 2), two alternative management options (superscripted 1 and 2), and two forest outputs produced over two planning time periods (timber 1, timber 2, range 1, range 2) are included. The upper level models developed in this analysis cover five time periods and include as many as 9 forest outputs, 19 forests, and 190 management alternatives.

In table 1, X_1^1 through X_2^2 are 0-1 decision variables representing selection (1) or rejection (0) of the discrete management alternatives developed by the national forests in their lower level planning analyses. The column vectors of outputs associated with each management alternative are collected in the first six rows (accounting rows) of the model and are represented by the A_{ij} matrix of physical product/cost coefficients (for i=1,...6, j=1,...,4). For example X_1^1 represents the selection (X_1^1=1) or rejection (X_1^1=0) of the vector of outputs A_{i1} for i=1,...,4 and cost A_{i1} for i=5,6 associated with management alternative 1 in forest 1. For this study, the costs are adjusted for inflation but are not discounted. The 0-1 constraint rows force the selection of only one alternative for each forest planning unit by constraining the aggregate value of a forest's decision variables to equal ("type" column) a value of 1 ("RHS" column). However, the decision variables in this model are continuous, such that for any X, $0 \leq X \leq 1$. Therefore, the solution may include a partial selection of management alternatives, the combination of which satisfies the 0-1 constraints. For example, the management alternative options available in forest 1, X_1^1 and X_2^1, might solve with values of 0.6 and 0.4, respectively.

Each accounting row is associated with an analogous accounting column. The accounting columns represent the regional production outputs and costs associated with the chosen solution. Thus, columns aggregate the outputs/costs of the alternatives selected in the solution. The aggregate outputs are then transferred to the production constraint rows and constrained to meet specified targets. For example, first period timber output (T1) is constrained to be greater than or equal to ($\geq$ type) K_1 (RHS).

Table 1.--An abbreviated upper level (regional) model structure.

		Decision variables				Accounting columns							
		Forest 1		Forest 2		Outputs				Cost 1	Cost 2	Type	Right-hand side
		X^1_1	X^1_2	X^2_1	X^2_2	T1	T2	R1	R2	C1	C2		(RHS)
Accounting rows	Timber 1	A_{11}	A_{12}	A_{13}	A_{14}	-1						=	0
	Timber 2	A_{21}	A_{22}	A_{23}	A_{24}		-1					=	0
	Range 1	A_{31}	A_{32}	A_{33}	A_{34}			-1				=	0
	Range 2	A_{41}	A_{42}	A_{43}	A_{44}				-1			=	0
	Cost 1	A_{51}	A_{52}	A_{53}	A_{54}					-1		=	0
	Cost 2	A_{61}	A_{62}	A_{63}	A_{64}						-1	=	0
	Objective Function									1	1		MIN
0-1 Decision variable constraints	Forest 1	1	1									=	1
	Forest 2			1	1							=	1
Production constraints (targets)	Timber 1					1						≥	K_1
	Timber 2						1					≥	K_2
	Range 1							1				≥	K_3
	Range 2								1			≥	K_4

Aggregate costs are transferred to the objective function row, and their sum is minimized.

This model is structured to minimize cost of regional forest production subject to constraints that force the selection of only one management alternative (and its corresponding vector of outputs and costs) per forest and that bound (constrain) the aggregate production of forest outputs.

Upper Level Model Algebraic Formulation

The algebraic representation of this model, along with definitions for subscripts and variables is:

$$\text{minimize:} \quad \sum_{t=1}^{5} \dot{C}_t \qquad \text{(objective function)}$$

$$\text{subject to:} \quad \sum_{j=1}^{n} \sum_{i=1}^{m} P_{ijpt} X_{ij} - T_{pt} = 0 \;\forall\, p, t$$

(Production Accounting Rows-Outputs)

$$\sum_{j=1}^{n} \sum_{i=1}^{m} C_{ijt} X_{ij} - \dot{C}_t = 0 \;\forall\, t$$

(Production Accounting Rows-Costs)

$$\sum_{i=1}^{m} X_{ij} = 1 \;\forall\, j$$

(0-1 Constraint Rows)

$$T_{pt} \underset{<}{\geq} K_{pt} \;\forall\, p, t$$

(Production Constraint Rows)

$$X_{ij} \geq 0 \;\forall\, i, j$$
$$T_{pt} \geq 0 \;\forall\, p, t$$
$$\dot{C}_t \geq 0 \;\forall\, t$$

(Non-negativity Constraints)

Definition of Subscripts

- i Represents a management alternative from a lower level model.
- j Represents a lower level model (forest).
- t Represents the time period.
- p Represents the product outputs from the lower level models considered in each upper level model.
- m Represents the number of management alternatives in a lower level model.
- n Represents the number of lower level models.

Definition of Variables

X_{ij} = Management alternative i from lower level planning unit (forest) j.

P_{ijpt} = Output of product p for time period t from management alternative i of forest j (A-matrix).

C_{ijt} = Cost of management alternative i from forest j and time period t (also part of A-matrix).

T_{pt} = A variable to transfer the aggregate output of product p for time period t from the production accounting rows to the production constraint rows.

C^{*}_{t} = A variable to transfer the aggregate cost for time period t from the production accounting rows to the objective function.

K_{pt} = The production target for aggregate output of product p for time period t.

DESCRIPTION OF UPPER LEVEL MODEL FORMULATIONS

This section describes each of the variables represented by the column and row headings in the original LP upper level model formulations and the model parameters (matrix coefficients) in detail. The variables are organized in a coded format to enhance computational efficiency and interpretation of solution outputs.

Decision Variable Columns

The dichotomous (0-1) decision variables are represented by the coding R#/#/#. For example, R1/1/1 represents region 1/ forest 1/alternative 1. Table 2 lists the forests, their assigned number, and the number of alternatives per forest by region. The table also identifies certain alternatives -- the No Action, Proposed, and RPA Alternatives -- by number and lists the code name for each forest represented in the 0-1 constraint rows that are analogous to the decision variable columns. The columns labeled DEIS and FEIS indicate the source of this forest production data, i.e., either the draft or final environmental impact statement, respectively.

The No Action, Proposed, and RPA Alternatives were specifically required by the NFMA. The No Action Alternative reflects the most likely condition expected if current management direction would continue unchanged. The RPA Alternative is designed to provide goods and services at levels assigned to a forest to meet its regionally-assigned share of national production goals (RPA targets). The Proposed Alternative is the alternative recommended for implementation as the forest plan. Each alternative in table 2 is fully described in the draft and/or final environmental impact statements (EIS) for each forest planning unit.

The alternatives considered were developed in response to legislation and regulations (NFMA, 36 CFR 219.12(f)), public issues, and management concerns. Each alternative represents a different management emphasis, which still maintains multiple-use constraints and an economic efficiency objective. The benchmark alternatives that maximize present net value PNV represent the optimum economic mix of outputs for a forest. Other benchmark alternatives were developed that established the maximum and minimum single resource output capability of a forest. These alternatives were not included in the resource interactions analysis, because a full set of output capabilities is not indicated for these alternatives. Finally, some additional alternatives were considered in the forest EIS's but then were eliminated from detailed analysis for reasons such as infeasibility of implementation, lack of responsiveness to public issues and/or management concerns, and violations of the NFMA. They were not included in this analysis for the same reasons.

Accounting Rows

The model tracks up to 9 outputs and cost over a 50-year planning horizon using five 10-year periods. Table 3 lists the outputs considered, their coding by planning period, their units of measurement, and the regional models in which each output is tracked. The model outputs were chosen based on a review of the EIS from each forest by region and the "initial data" set described below. Summary tables were utilized that indicated full and partial scheduling, and indicated every output/forest/ scheduling combination that is reported in the EIS's. Analysis of the completed tables resulted in the decisions reported in table 3. It was intended that the outputs in table 3 represent the most consistently and fully reported of the range of outputs scheduled by each forest and region, and the outputs included were selected as the most appropriate data available for demonstrating resource interactions.

The 50-year planning horizon covers either the years from 1981 to 2030 or 1986-2035, depending upon when a region began its planning process. The planning horizon is noted in the "initial data" recording matrix for each forest (described below). Dispersed recreation outputs include wilderness recreation visitor days (RVD) and wildlife and fish user days (WFUD) and are recorded as projected use. If capacity is reported and use is unavailable, capacity is recorded. Region 1 is the only region where total dispersed recreation (REC) was sufficiently disaggregated to record motorized (RECM) and nonmotorized (RECNM) dispersed recreation separately.

Wildlife habitat improvements (HAB) are defined as projects undertaken directly for the benefit of wildlife (individual forests may target any one or combination of game, nongame, and endangered species). This output is reported in acres or acre equivalents and is recorded as acres (# ACRES). Either elk (ELK) or deer (DEER) is recorded as the management indicator species (MIS) in the data set. The MIS are considered representative of the species that inhabit the planning area of a forest and lower level forest planning focuses on these species in order to maintain viable populations of all existing native vertebrates. These wildlife outputs are recorded as potential (capacity) or projected populations (#ELK or #DEER). If both a winter and summer range population is reported, the larger of the two is recorded.

Table 2.--Decision variable coding.

Coding Example: R1/8/5=Region 1/Helena NF/Proposed Alternative

Region #	Forest	Forest code name	Forest #	# of alts.	No action alt. #	Proposed alt. #	RPA alt. #	DEIS	FEIS
1	Beaverhead	BEAVERHD	1	12	1	7	2	x	
1	Bitterroot	BITTERRT	2	10	6	4	1	x	
1	Clearwater	CLEARWTR	3	12	1	5	3	x	
1	Custer	CUSTER	4	17	5	9	2	x	
1	Deerlodge	DEERLDGE	5	14	1	12	3	x	
1	Flathead	FLATHEAD	6	19	7	11	2	x	
1	Gallatin	GALLATIN	7	11	1	7	4	x	
1	Helena	HELENA	8	11	1	5	2	x	
1	Idaho Panhandle	IDAHOPAN	9	13	8	11	1	x	
1	Lewis & Clark	LEWISCLK	10	17	1	12	2	x	
1	Lolo	LOLO	11	9	1	4	8	x	
1	Nezperce	NEZPERCE	12	30	1	6	4	x	
1	Kootenai	KOOTENAI	13	15	9	10	4	x	
2	Arapaho & Roosevelt	ARAPAHO	1	7	2	1	1		x
2	Bighorn	BIGHORN	2	8	2	1	3		x
2	Black Hills	BLACKHLS	3	10	6	1	10		x
2	Grand Mesa, Uncompahgre, Gunnison	GRANDMSA	4	9	2	1	3		x
2	Medicine Bow	MEDICINE	5	10	2	1	3		x
2	Nebraska	NEBRASKA	6	8	5	6	7		x
2	Pike & San Isabel	PIKE	7	5	2	1	3		x
2	Rio Grande	RIOGRDE	8	9	2	1	3		x
2	Routt	ROUTT	9	6	2	1	3		x
2	San Juan	SAN JUAN	10	10	6	8	5		x
2	Shoshone	SHOSHONE	11	6	1	4	6	x	
2	White River	WHITERVR	12	6	2	1	3		x
3	Apache-Sitgreaves	APACHE	1	6	6	1	5	x	
3	Carson	CARSON	2	7	2	1	3	x	
3	Cibola	CIBOLA	3	7	2	1	3		x
3	Coconino	COCONINO	4	8	2	1	3	x	
3	Coronado	CORONADO	5	6	2	1	3	x	
3	Gila	GILA	6	8	2	1	3	x	
3	Kaibab	KAIBAB	7	7	2	1	3	x	
3	Lincoln	LINCOLN	8	6	2	1	3	x	
3	Prescott	PRESCOTT	9	7	2	1	3	x	
3	Santa Fe	SANTA FE	10	7	3	1	2	x	
3	Tonto	TONTO	11	9	4	9	3		x
4	Ashley	ASHLEY	1	9	1	2	5	x	
4	Caribou	CARIBOU	2	15	1	10	7		x
4	Challis	CHALLIS	3	11	1	11	2	x	
4	Dixie	DIXIE	4	8	1	2	7	x	
4	Fishlake	FISHLAKE	5	11	8	11	5	x	
4	Humboldt	HUMBOLDT	6	11	6	9	5	x	
4	Manti-LaSal	MANTI	7	8	1	8	4	x	
4	Payette	PAYETTE	8	12	1	10	6	x	
4	Salmon	SALMON	9	12	1	12	4	x	
4	Sawtooth	SAWTOOTH	10	12	1	2	5	x	
4	Targhee	TARGHEE	11	8	4	3	2		x
4	Toiyabe	TOIYABE	12	9	1	6	4	x	
4	Wasatch-Cache	WASATCH	13	8	1	8	2		x
4	Bridger-Teton	BRIDGER	14	10	4	10	3	x	
5	Angeles	ANGELES	1	9	2	1	3	x	
5	Cleveland	CLEVE	2	7	2	1	3		x
5	Eldorado	ELDORADO	3	9	2	1	1	x	
5	Inyo	INYO	4	6	2	1	3	x	

(Continued)

Table 2.--(continued).

Region #	Forest	Forest code name	Forest #	# of alts.	No action alt. #	Proposed alt. #	RPA alt. #	DEIS	FEIS
Coding Example: R1/8/5=Region 1/Helena NF/Proposed Alternative									
5	Lassen	LASSEN	6	9	2	1	3	x	
5	Los Padres	LOS PADR	7	10	2	1	7	x	
5	Mendocino	MENDOCINO	8	8	2	1	3	x	
5	Plumas	PLUMAS	10	6	2	1	3	x	
5	San Bernardino	SAN BERN	11	6	2	1	3	x	
5	Sequoia	SEQUOIA	12	10	2	1	3	x	
5	Shasta-Trinity	SHASTA	13	7	2	1	3	x	
5	Sierra	SIERRA	14	10	2	1	3	x	
5	Six Rivers	SIX RIV	15	8	2	1	3	x	
5	Stanislaus	STANISLA	16	8	3	1	4	x	
5	Tahoe	TAHOE	17	11	2	1	3	x	
8	Alabama	ALABAMA	1	6	1	6	5	x	
8	Chattahoochee Oconee	CHATOCON	2	6	3	6	2		x
8	Cherokee	CHEROKEE	3	6	1	6	2	x	
8	Croatan-Uwharrie	CROATUWH	4	10	1	5	2	x	
8	Daniel Boone	DANBOONE	5	12	1	10	2	x	
8	Florida	FLORIDA	6	9	2	7	1	x	
8	Francis Marion	FRANCISM	7	8	1	5	2		x
8	George Washington	GEOWASH	8	8	1	8	7	x	
8	Jefferson	JEFFERSN	9	11	2	1	10		x
8	Kisatchie	KISATCH	10	11	1	4	3		x
8	Mississippi	MISSIPPI	11	8	2	5	6		x
8	Nantahala-Pisgah	NANPISG	12	10	1	7	2	x	
8	Ouachita	OUACHITA	13	10	1	4	2	x	
8	Ozark-St. Francis	OZARKSTF	14	8	8	4	7	x	
8	Sumter	SUMTER	15	11	1	10	2		x
8	Texas	TEXAS	16	12	5	10	3	x	
9	Allegheny	ALEGHENY	1	7	2	4	2	x	
9	Chequamegon	CHEQUAM	2	11	1	7	8	x	
9	Chippewa	CHIPPEWA	3	8	2	3	3	x	
9	Green Mountain	GREEN MT	4	6	1	4	2	x	
9	Hiawatha	HIAWATHA	5	7	5	7	4	x	
9	Hoosier	HOOSIER	6	8	1	4	4		x
9	Huron-Manistee	HURON	7	9	3	7	7	x	
9	Mark Twain	MARK TWN	8	7	7	5	5	x	
9	Monongahela	MONONGA	9	5	1	5	4	x	
9	Nicolet	NICOLET	10	9	1	5	2	x	
9	Ottawa	OTTAWA	11	10	2	7	6	x	
9	Shawnee	SHAWNEE	12	10	2	4	8	x	
9	Superior	SUPERIOR	13	8	1	6	5	x	
9	Wayne	WAYNE	14	7	1	3	5	x	
9	White Mountain	WHITE MT	15	5	1	5	2	x	

Table 3.--Forest outputs.

Output	Accounting rows code (by period 1-5)	Accounting columns code (by period 1-5)	Measurement units (aver. annual)	Forest region reporting
Dispersed motorized recreation	RECM1	RECM1P		
	RECM2	RECM2P		
	RECM3	RECM3P	MRVD	1
	RECM4	RECM4P		
	RECM5	RECM5P		

(Continued)

Table 3.–(continued)

Output	Accounting rows code (by period 1-5)	Accounting columns code (by period 1-5)	Measurement units (aver. annual)	Forest region reporting
Dispersed nonmotorized recreation	RECNM1 RECNM2 RECNM3 RECNM4 RECNM5	RECNM1P RECNM2P RECNM3P RECNM4P RECNM5P	MRVD	1
Total dispersed recreation	REC1 REC2 REC3 REC4 REC5	REC1P REC2P REC3P REC4P REC5P	MRVD	2,3,4,5,8,9
Wildlife habitat improvement	HAB1 HAB2 HAB3 HAB4 HAB5	HAB1P HAB2P HAB3P HAB4P HAB5P	# ACRES	1,2,3,4,5,8,9
Elk	ELK1 ELK2 ELK3 ELK4 ELK5	ELK1P ELK2P ELK3P ELK4P ELK5P	# ELK	1,2,3,4
Deer	DEER1 DEER2 DEER3 DEER4 DEER5	DEER1P DEER2P DEER3P DEER4P DEER5P	# DEER	5,8
Fish	FISH1 FISH2 FISH3 FISH4 FISH5	FISH1P FISH2P FISH3P FISH4P FISH5P	MFISH or MLBS	1,5
Range	RNG1 RNG2 RNG3 RNG4 RNG5	RNG1P RNG2P RNG3P RNG4P RNG5P	MAUM	1,2,3,4,5,8,9
Timber	TMBR1 TMBR2 TMBR3 TMBR4 TMBR5	TMBR1P TMBR2P TMBR3P TMBR4P TMBR5P	MMCF	1,2,3,4,5,8,9
Water Yield	WTR1 WTR2 WTR3 WTR4 WTR5	WTR1P WTR2P WTR3P WTR4P WTR5P	MACFT	1,2,3,4,5,8
Sediment Yield	SDMT1 SDMT2 SDMT3 SDMT4 SDMT5	SDMT1P SDMT2P SDMT3P SDMT4P SDMT5P	MTONS	1,2,3,4,5,8
Cost	COST1 COST2 COST3 COST4 COST5	COST1P COST2P COST3P COST4P COST5P	MM1978$ or MM1982$	1,2,3,4,5,8,9

Fish (FISH) are recorded either by potential population (MFISH) or weight (MLBS), the metric being consistent for any single region. Fish are reported in several different categories; non-wilderness fish in streams, fish in streams, catchable trout in streams, anadromous, etc. These are aggregated into one category, i.e., fish, for the purposes of this analysis. Range (RNG) is reported as projected or permitted grazing use and these are recorded in thousands of animal unit months (MAUM). If capacity is reported and use data is unavailable, capacity is recorded.

The timber output (TMBR) recorded includes allowable sale plus any additional products such as fuelwood, posts and poles, or biomass. Allowable sale is the quantity of timber that may be sold from the area of suitable land covered by the forest plan for a time period specified in the plan. If allowable sale is not reported, programmed sales offered is used. Programmed sales offered is allowable sale plus an unregulated volume. Timber is recorded in millions of cubic feet (MMCF).

Water (WTR) is recorded as total projected yield in thousands of acre feet (MACFT) and sediment (SDMT) is recorded as total projected yield in thousands of tons (MTONS).

Costs (COST) recorded include operating and maintenance and capital investment costs (these come from appropriated funds), timber purchaser road credits (for roads built by timber purchasers), and forest fire fighting funds. The costs recorded exclude allocated and cooperator funds. Allocated funds are federal funds appropriated for an agency or program outside the Forest Service but applied to Forest Service projects (for example, land acquisitions using Land and Water Conservation funds). Cooperator funds cover non-federal costs such as State Fish and Game expenditures for projects on Forest Service lands. All of the outputs and costs are recorded by period on an average annual basis.

Production Coefficients (A-Matrix)

The column vectors of physical production and cost coefficients quantify the mix of outputs and cost associated with particular management alternatives and forests. The individual outputs and cost from each column vector are collected in the accounting rows. These column and row vectors represent the A-matrix of technological coefficients in the upper level LP models. These coefficients were extracted either directly or indirectly from the schedules of outputs reported, by alternative, in the EIS of each national forest.

Indirect methods of data collection were required because not all of the model outputs in table 3 were fully scheduled in the EIS's. In such cases, the missing data were either obtained from a forest or regional planning team (from other forest planning records or the teams best estimate) or were estimated using the data available with regression, interpolation, or other techniques (discussed in the section on methodologies for dealing with data deficiencies). Many output measurement units were not consistent with those in table 3. Factors for conversions to common units either were obtained from the forests or regions, or were estimated based on extrapolations from the data available.

In some cases, the data available were insufficient to warrant any estimations, and the affected alternatives were eliminated from the analysis. The most frequently eliminated alternatives were benchmark alternatives which displayed the most data omissions. The objective was to minimize the amount of estimated data, but at the same time preserve a wide range of alternatives.

The remainder of this section examines, in detail, the initial data recording procedure, and the methodologies for dealing with data deficiencies. To conserve space and avoid redundancy, it will not cover every deficiency or every alternative output vector in the entire set considered. A comprehensive illustration using the Bridger-Teton National Forest in Region 4 is presented. In addition, examples of other distinct methodologies used in the direct recording and estimation of production data are reviewed.[2]

Initial Data Recording

Production coefficients by forest were recorded manually in a matrix format. Table 4 shows the matrix format and the initial nonhomogenous recording of data for the Bridger-Teton National Forest.[3] In this particular EIS, the primary and benchmark alternatives were scheduled (except for cost) in separate (but similar) tables, and two separate schedules for costs (primary and benchmark) also were reported. Most forest EIS's have schedules of resource activity outputs and costs similar to those for the Bridger-Teton. However, some EIS's display separate output schedules for each alternative; and there were many cases where the data recording relied on singular output schedules reported in the resource descriptions or environmental consequences sections of the EIS. There also were instances where data necessary for the direct derivation or estimation of production coefficients were found within the text.

Note that in the data recording matrix (table 4), the rows represent outputs by period and the columns represent planning alternatives. The number that heads each column is the coding number for that alternative in the decision variable code (for example, the proposed alternative from the Bridger-Teton would be identified by the decision variable code R4/14/10--see table 2). The number directly under the column heading number is the identification given to each alternative in the EIS itself. Alternative 11 and 12 are the maximum PNV benchmark alternatives and are identified by adding the prefix "BM-" to the number assigned in the EIS. Finally, the RPA, No Action, and Proposed Alternatives are identified in the recording process.

The data in the initial recording either were copied or derived directly from the schedules of outputs in the EIS. For example, wildlife habitat improvement (HAB) and range (RNG) data for the Bridger-Teton NF were taken directly from the schedules in

[2]Complete information about all of the technological coefficients in the A-matrix for each regional model is documented in notes maintained in research unit RM-4851 at the Rocky Mountain Forest and Range Experiment Station.

[3]The schedules of outputs in the Bridger-Teton National Forest Draft Environmental Impact Statement (EIS), from which these data were obtained, are on pages II-28 through II-44 and B-III-5 through B-III-26.

Table 4.–Bridger-Teton National Forest production coefficients -- initial data recording (nonhomogenous).

			Alternatives											
			1	2	3	4	5	6	7	8	9	10	11	12
Period	Units	Output	1	2	3	4	5	6	7	8	9	10	BM-2	BM-3
					RPA	No Action						Proposed	Max PNV	
													Mkt. outputs	All outputs
		REC												
1986 1995	MRVD's		1795.7	1797.3	1915.8	1853.1	1854.8	1880.4	1812.6	1814.9	1835.1	1848.8	1787.6	1850.5
1996 2005			2546.1	2546.5	2620.9	2526.4	2528.2	2563.5	2463.5	2467.1	2497.1	2513.9	2540.1	2516.2
2006 2015			3214.7	3214.2	3241.5	3117.3	3119.1	3161.9	3035.6	3035.9	3075.5	3098.5	3218.4	3101.1
2016 2025			4035.8	4034.6	4017.8	3859.2	3860.7	3914.5	3753.8	3755.9	3806.2	3831.0	4041.2	3834.4
2026 2035			4744.8	4743.4	4681.3	4489.1	4490.6	4553.1	4362.3	4362.0	4423.0	4453.6	4752.0	4457.2
		HAB												
1	#ACRES		0	0	301	672	672	330	682	2299	672	1008	0	2866
2			0	0	301	672	672	331	682	2299	672	1008	0	2866
3			0	0	301	672	684	331	694	2299	678	1020	0	2883
4			0	0	301	672	713	331	697	2371	749	1117	268	2889
5			0	0	426	966	966	466	996	2608	966	1406	268	3126
		ELK												
1	#ELK													
2														
3														
4														
5			13000	13500	18500	17800	17500	20000	21000	21500	21000	21500		
		RNG												
1	MAUM		263.3	263.3	257.8	255.2	255.2	255.9	255.2	261.9	255.2	255.2	238.9	255.2
2			273.1	273.1	260.2	257.5	257.5	258.3	257.5	262.8	257.5	257.5	239.1	257.5
3			282.5	282.5	261.7	258.9	258.9	259.8	258.9	263.3	258.9	258.9	239.2	258.9
4			291.7	291.7	263.4	260.4	260.5	261.5	260.5	264.0	260.4	260.5	239.2	260.4
5			300.7	300.7	266.9	263.8	264.0	264.9	264.0	265.5	263.9	264.0	239.9	263.9
		TMBR												
1	MMCF													
2														
3														
4														
5														
		WTR												
1	MACFT		5740.3	5735.5	5733.6	5730.6	5730.6	5728.4	5730.3	5726.1	5728.0	5728.9	5743.7	5728.2
2			5771.4	5756.0	5749.0	5739.6	5740.0	5733.2	5738.9	5726.1	5733.6	5735.3	5782.4	5732.6
3			5792.1	5768.9	5757.3	5746.1	5743.3	5735.9	5743.4	5726.1	5739.2	5740.5	5806.2	5735.9
4			5793.1	5771.2	5757.2	5749.7	5745.3	5735.9	5743.5	5726.1	5740.8	5743.1	5807.0	5737.8
5			5783.7	5771.4	5756.3	5750.7	5744.2	5735.8	5745.4	5726.1	5740.7	5744.0	5799.9	5740.5
		SDMT												
1	MTONS													
2														
3														
4														
5														

(Continued)

Table 4.--(continued).

			Alternatives											
			1	2	3	4	5	6	7	8	9	10	11	12
Period	Units	Output	1	2	3	4	5	6	7	8	9	10	BM-2	BM-3
					RPA	No Action						Proposed	Max PNV	
													Mkt. outputs	All outputs
		COST												
1	MM1978$		7.90	6.60	6.16	5.27	5.23	4.53	5.95	3.16	4.52	4.95	8.10	4.77
2			8.79	7.96	6.17	4.88	4.92	4.73	6.01	3.19	5.15	5.56	9.35	5.30
3			9.02	7.37	6.45	5.74	5.03	4.93	6.14	3.23	5.33	6.01	9.21	5.63
4			8.01	7.52	6.76	5.61	4.95	5.12	6.30	3.28	5.51	6.18	8.99	6.02
5			7.22	7.54	6.74	5.69	5.02	5.41	7.12	3.38	5.89	6.48	7.97	6.62

the EIS, while dispersed recreation (REC) and water yield (WTR) data are fully reported in the EIS tables, but in a disaggregated state. Table II-17 on page II-125 of the Bridger-Teton EIS disaggregates total recreation and indicates that dispersed recreation includes wildlife and fish user days (WFUD) but not wilderness recreation. Thus, dispersed and wilderness recreation are summed to derive the total dispersed recreation recorded in table 4. The water yield reported in the EIS is not total yield but the increase over "natural yield." However, the natural level is implicitly revealed in this table (see water meeting quality goals, alternative 8). Therefore, total water yield is derived directly from the schedule by adding water yield increases to this natural level. Cost also is fully scheduled in the EIS, but in 1982 dollars. It is a straightforward procedure to convert these costs to 1978 dollars. The reported cost is simply multiplied by the appropriate price deflator 150.42/207.38. The only other data that could be recorded directly from the EIS was the partial reporting for elk (ELK). This data came from a bar graph on page II-130 of the EIS.

This initial record of production coefficients is referred to as the nonhomogenous data set, because it is not only incomplete with respect to the outputs to be modeled (table 3) but also incommensurate between forests.

Methodologies for Dealing with Data Deficiencies

After the initial recording of production coefficients, data deficiencies and inconsistencies could be identified. For example, inconsistencies in the reporting of elk, timber, sediment and cost were noted for the Bridger-Teton National Forest as follows. Elk was not reported in periods 1 through 4 for the primary alternatives and not at all for the benchmarks. Timber was made up of three separately reported components; allowable sale, fuelwood, and other products. Allowable sale was fully reported in millions of cubic feet (MMCF) for all alternatives. Other products and fuelwood also were fully reported for all the alternatives, but were reported in board feet (BF), and a BF to CF conversion ratio was not given. Sediment yield was not reported. However, a natural sediment rate of 195,000 tons/yr was reported (page IV-65 of the EIS) and it was indicated in the text that the yield over natural was scheduled in other forest records. Finally, the inclusion or exclusion of allocated funds in the cost figures could not be ascertained from the EIS, although costs were otherwise fully reported and could be directly recorded. In such cases, it was assumed that allocated funds were not included and reported costs were matriculated in the initial recording process. However, if the forest planning team was contacted to obtain other data, they were also asked about allocated funds. Therefore, the disposition of allocated funds was always noted in this process of defining deficiencies.

The next step in completing the recording of a forest's production data set involved contacting the forest planning team to see if any of the missing data was available from other planning records, or if the team could provide their best estimates. In the case of the Bridger-Teton National Forest, the planning team was able to provide the following data: first period elk for primary alternatives, BF to CF conversion ratios for both fuelwood and other products (posts and poles), and the schedule of sediment yield over natural for the primary alternatives. The Forest planning team also indicated that allocated funds were insignificant.

These additional data obtained from a forest either were transferred directly to the data recording matrix or were transferred after appropriate manipulations. For example, only the elk data provided by the Bridger-Teton could be directly recorded. BF to CF conversion ratios supplied by the forest were applied to the timber outputs reported in BF before all timber outputs could be aggregated and recorded and sediment yields over natural were added to the natural yield reported to obtain the total yield to be recorded.

Finally, estimation strategies were formulated and implemented for data deficiencies still existing after forest contact and the subsequent transformation and recording of data provided by the forest planning team. For the Bridger-Teton, these data gaps included elk in periods 2, 3, and 4 for the primary alternatives,

Table 5.–Bridger-Teton National Forest production coefficients -- complete data recording (homogenous).

			Alternatives									
			1	2	3	4	5	6	7	8	9	10
Period	Units	Output	1	2	3 RPA	4 No action	5	6	7	8	9	10 Proposed
		REC										
1	MRVD		1795.7	1797.3	1915.8	1853.1	1854.8	1880.4	1812.6	1814.9	1835.1	1848.8
2			2546.1	2546.5	2620.9	2526.4	2528.2	2563.5	2463.5	2467.1	2497.1	2513.9
3			3214.7	3214.2	3241.5	3117.3	3119.1	3161.9	3035.6	3035.9	3075.5	3098.5
4			4035.8	4043.6	4017.8	3859.2	3860.7	3914.5	3753.8	3755.9	3806.2	3831.0
5			4744.8	4743.4	4681.3	4489.1	4490.6	4553.1	4362.3	4362.0	4423.0	4453.6
		HAB										
1	#ACRES		0	0	301	672	672	330	682	2299	672	1008
2			0	0	301	672	672	331	682	2299	672	1008
3			0	0	301	672	684	331	694	2299	678	1020
4			0	0	301	672	713	331	697	2371	749	1117
5			0	0	426	966	966	466	996	2608	966	1406
		ELK										
1	#ELK		17800	17800	17800	17800	17800	17800	17800	17800	17800	17800
2			16500	16725	17975	17800	17725	18350	18600	18725	18600	18725
3			15400	15650	18150	17800	17650	18900	19400	19650	19400	19650
4			14200	14575	18325	17800	17575	19450	20200	20575	20200	20575
5			13000	13500	18500	17800	17500	20000	21000	21500	21000	21500
		RNG										
1	MAUM		263.3	263.3	257.8	255.2	255.2	255.9	255.2	261.9	255.2	255.2
2			273.1	273.1	260.2	257.5	257.5	258.3	257.5	262.8	257.5	257.5
3			282.5	282.5	261.7	258.9	258.9	259.8	258.9	263.3	258.9	258.9
4			291.7	291.7	263.4	260.4	260.5	261.5	260.5	264.0	260.4	260.5
5			300.7	300.7	266.9	263.8	264.0	264.9	264.0	265.5	263.9	264.0
		TMBR										
1	MMCF		43.22	28.70	22.73	13.37	13.37	6.88	12.12	0	5.58	8.54
2			53.91	34.28	24.30	13.37	14.70	7.93	14.17	0	12.06	11.44
3			55.60	35.58	24.54	20.89	15.44	7.93	14.17	0	12.06	15.06
4			44.55	36.50	24.38	20.75	15.30	7.91	14.41	0	11.94	15.06
5			35.59	36.52	24.54	20.89	15.44	8.17	20.39	0	12.60	15.06
		WTR										
1	MACFT		5740.3	5735.5	5733.6	5730.6	5730.6	5728.4	5730.3	5726.1	5728.0	5728.9
2			5771.4	5756.0	5749.0	5739.6	5740.0	5733.2	5738.9	5726.1	5733.6	5735.3
3			5792.1	5768.9	5757.3	5746.1	5745.3	5735.9	5743.4	5726.1	5739.2	5740.5
4			5793.1	5771.2	5757.2	5749.7	5745.3	5735.9	5743.5	5726.1	5740.8	5743.1
5			5783.7	5771.4	5756.3	5750.7	5744.2	5735.8	5745.4	5726.1	5740.7	5744.0
		SDMT										
1	MTONS		212.83	212.83	202.24	201.80	201.80	198.63	198.33	197.02	198.50	198.05
2			213.02	213.02	203.15	201.50	201.50	198.25	198.53	197.10	198.07	198.42
3			213.62	213.62	202.41	201.43	201.43	198.22	198.38	196.90	197.96	198.31
4			215.55	215.55	202.65	201.01	201.01	198.46	198.64	197.16	198.11	198.57
5			214.73	214.73	202.23	200.38	200.38	198.03	198.18	196.92	197.92	198.12
		COST										
1	MM1978$		7.90	6.60	6.16	5.27	5.23	4.53	5.95	3.16	4.52	4.95
2			8.79	7.96	6.17	4.88	4.92	4.73	6.01	3.19	5.15	5.56
3			9.02	7.37	6.45	5.74	5.03	4.93	6.14	3.23	5.33	6.01
4			8.01	7.52	6.76	5.61	4.95	5.12	6.30	3.28	5.51	6.18
5			7.22	7.54	6.74	5.69	5.02	5.41	7.12	3.38	5.89	6.48

the full schedule of elk for the benchmark alternatives, and the full schedule of sediment yield for the benchmarks. A straightforward interpolation between period 1 and 5 data provided the estimates for elk under the primary alternatives. There was no acceptable method available for estimating the full schedules of elk or sediment yield in the benchmark alternatives. Therefore, a judgment was made to eliminate the benchmark alternatives from the analysis because of insufficient data.

Table 5 represents the completed homogenous data matrix for the Bridger-Teton National Forest. The complete production data set for a forest is referred to as the homogenous set since the recorded production data are analogous for all forests in a region, and, therefore, suitable for interactions analysis. Appendix 1 shows the entire procedure for recording the homogenous set of production coefficients for the Bridger-Teton National Forest as it is documented in the study notes. This documentation format, used for each forest planning unit in the National Forest System, encompasses the following: the initial data available from the forest EIS, identification of data deficiencies, data obtained from forest contact, disposition of data provided by the forest, identification of deficiencies remaining after forest contact, techniques used to estimate missing data, and any elimination of alternative output vectors. Table 6 is a summary of the disposition of the entire set of production coefficients in the Region 4 model by forest and output.

To conserve space and still provide sufficient documentation as to the range of methodologies employed in this study, a format similar to Appendix 1 is utilized to present examples from other forests and regions. These examples cover the distinct methodologies that were utilized for the direct derivation and/or indirect estimation of dispersed recreation, wildlife habitat improvement, elk, deer, fish, range, timber, water yield, sediment yield, and cost in Appendix 2.

The general approach taken for handling data deficiencies when simple unit conversions, interpolations, and extrapolations were not feasible, was to apply simple linear regression to use some explanatory variable to predict the missing forest production data (mainly sediment and water yields). A straight-line linear model in two variables is expressed as $y=a+bx$, where y is the dependent variable, x is the independent variable, a is the y-intercept, and b is the slope. Such a line can be fitted to a sample of known data points (x,y), and the resulting equation is used to estimate an unknown dependent variable, y, given a known predictor variable, x. For example, assume that sediment yield for a particular forest is only partially scheduled. Further assume that road construction bears a direct linear relationship to the amount of total sediment yield on the forest and that this output is fully scheduled. The available sediment data and the analagous portion of road construction data were then used to fit a linear equation. This equation was then used in conjunction with the remaining road construction data to predict the unscheduled sediment yields. It would be useful to know the strength of the relationship between sediment yield and road construction in this problem. If the relationship is very weak or nonexistent, we would want to explore other approaches to the problem of estimating the unscheduled sediment yield data. The correlation coefficient (r) was used for this purpose.

Road construction, the independent variable generally used in the estimation of sediment yield, is assumed not to have carryover effects on the sediment yields in succeeding decades --assuming most roads will be closed and stabilized, the carryover effect on sediment yield is significantly diminished within 5 to 7 years. Conversely, timber harvesting, the activity with the greatest effect on water yield, is assumed to have long-term effects. In this study, a percentage of allowable sale is carried over from preceding to succeeding decades to account for this effect. The carryover is based on an assumed percentage carryover of water yield from the initial harvest through the 1st, 2nd, 3rd, and 4th decades of 75%, 66%, 50%, and 33%, respectively. These carryover percentage estimates resulted from discussions with several forest system hydrologists and are based on their professional judgments. The allowable sale data carried over are called allowable sale equivalents, because they are added to the current year's allowable sale for purposes of predicting current water yield. Thus, allowable sale equivalents encompass the carryover of water yield still being generated from prior years' harvest activities. Appendix 2 presents specific examples of these calculations, as well as the more straightforward calculations for outputs other than water yield and sediment yield.

Not all of the forest planning units had completed their EIS's by the time the models in this study became functional. Thus, the Boise NF in Region 4 and the Klamath and Modoc NFs in Region 5 are not included in their respective regional models, and Region 6 is not yet included in the analysis, because most of its forests' EIS's are unavailable. Furthermore, most of the production data available came from draft environmental impact statements (DEIS), the initial planning document submitted for public review and subject to revision before the final environmental impact statements (FEIS) were prepared. Table 2 includes two columns indicating the source of production data for each forest planning unit, the DEIS or FEIS. Finally, there are 16 forest planning units whose FEIS's are now available but whose study data came from their DEIS's, again because the models were operational before these FEIS's became available. Table 7 lists these forests by region.

0-1 Decision Variable Constraints

The 0-1 constraint rows are represented by the code names for each forest (from table 2). The management alternatives from each forest are represented in their respective 0-1 rows by assigning each a coefficient of 1 in this row. Then only one alternative (or combination of alternatives equaling one) can be selected to be in the solution by assigning a RHS value of 1 to each 0-1 equality constraint row.

Accounting Columns

The accounting columns aggregate the output production (cost) from the management alternatives selected to be in solution, and represent the total produced (spent) as a column in the matrix. The activity level of these columns is the amount of

Table 6.--Disposition of production coefficients in Region 4 Model.

Initial # alts.		Forest[3]	Output	Fully sched-uled		Partially sched-uled		Unsched-uled		Conver-sion factor needed		Data provided by Forest		Data estimated interpola-tion		Data estimated regres-sion		Data estimated other		Alterna-tives elimi-nated	
P[1]	BM[2]			P	BM	P	BM	P	BM	P	BM	P	BM	P	BM	P	BM	P	BM	P	BM
9	2	Ashley																		0	1
			REC	X			X														
			HAB	X			X														
			ELK	X			X														
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SDMT	X	X																
			COST	X			X			X	X										
13	2	Caribou																		0	0
			REC	X	X																
			HAB	X	X																
			ELK					X	X			X	X								
			RNG	X	X																
			TMBR	X	X					X	X										
			WTR	X	X																
			SDMT	X					X								X				
			COST	X	X																
11	2	Challis																		0	2
			REC	X	X																
			HAB	X	X																
			ELK	X					X				X								
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SDMT					X	X			X					X				
			COST	X	X					X	X										
8	2	Dixie																		0	2
			REC	X	X																
			HAB	X	X																
			ELK	X					X												
			RNG	X	X																
			TMBR	X	X					X	X					X	X				
			WTR	X	X																
			SDMT					X	X	X		X				X					
			COST	X	X					X	X										
		Fishlake																		0	2
			REC	X	X																
			HAB	X	X																
			ELK	X					X			X									
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SMDT			X			X			X			X						
			COST	X	X					X	X										
9	2	Humboldt																		0	0
			REC	X	X																
			HAB	X	X																
			ELK					X	X			X	X								
			RNG	X	X																
			TMBR	X	X					X	X										
			WTR	X	X																
			SDMT			X	X					X	X					X	X		
			COST	X	X					X	X		X								

(Continued)

Table 6.--(continued).

Initial # alts.		Forest[3]	Output	Fully sched-uled		Partially sched-uled		Unsched-uled		Conver-sion factor needed		Data provided by Forest		Data estimated interpola-tion		Data estimated regres-sion		Data estimated other		Alterna-tives elimi-nated	
P[1]	BM[2]			P	BM	P	BM	P	BM	P	BM	P	BM	P	BM	P	BM	P	BM	P	BM
8	3	Manti-LaSal																		0	3
			REC	X			X							X							
			HAB			X			X				X								
			ELK	X			X							X							
			RNG	X			X							X							
			TMBR	X			X							X							
			WTR			X	X						X	X							
			SDMT			X			X						X	X					
			COST			X	X						X	X							
10	2	Payette																		0	0
			REC	X	X																
			HAB	X	X																
			ELK					X	X			X	X								
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SDMT					X	X			X	X								
			COST	X	X					X	X										
12	2	Salmon																		0	2
			REC	X	X																
			HAB	X	X																
			ELK					X	X			X									
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SDMT			X			X			X						X			
			COST	X	X					X	X										
12	2	Sawtooth																		0	2
			REC	X	X																
			HAB	X	X																
			ELK					X	X			X									
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SDMT			X			X			X						X			
			COST	X	X					X	X										
8	0	Targhee																		0	0
			REC	X																	
			HAB	X																	
			ELK					X				X									
			RNG	X																	
			TMBR	X						X		X									
			WTR	X																	
			SDMT					X										X			
			COST	X																	
9	2	Toiyabe																		0	2
			REC	X	X																
			HAB	X	X																
			ELK					X	X			X	X								
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SDMT					X	X			X	X					X	X		
			COST	X	X																

(Continued)

Table 6.--(continued).

Initial # alts. P[1]	Initial # alts. BM[2]	Forest[3]	Output	Fully scheduled P	Fully scheduled BM	Partially scheduled P	Partially scheduled BM	Unscheduled P	Unscheduled BM	Conversion factor needed P	Conversion factor needed BM	Data provided by Forest P	Data provided by Forest BM	Data estimated interpolation P	Data estimated interpolation BM	Data estimated regression P	Data estimated regression BM	Data estimated other P	Data estimated other BM	Alternatives eliminated P	Alternatives eliminated BM
8	2	Wasatch-Cache																		0	2
			REC	X	X																
			HAB	X	X																
			ELK	X	X																
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SDMT			X			X			X						X			
			COST	X	X																
10	2	Bridger-Teton																		0	2
			REC	X	X																
			HAB	X	X																
			ELK			X			X			X		X							
			RNG	X	X																
			TMBR	X	X					X	X	X	X								
			WTR	X	X																
			SDMT			X	X					X									
			COST	X	X					X	X										

[1] *P = Primary alternatives (alternatives considered in detail).*

[2] *BM = Benchmark alternatives (Max. PNV).*

[3] *Uinta National Forest did not schedule any outputs -- forest indicated unavailable.*

production (expenditure) associated with the row. This aggregation is achieved by assigning a subtraction operator (-) and unity coefficient (1) to the appropriate column and cell and setting equality type rows with RHS values of zero. Table 3 lists the code for the forest product outputs represented by the accounting columns.

Objective Function Row

The costs collected in the accounting columns are transferred to the objective function row. The objective function row forces the LP algorithm to minimize the costs of producing the required output levels. To achieve this transfer and minimization of costs, the coefficients in this row must be positive and unitary (1). The code for the objective function row is "MINOBJ".

Table 7.--Forests whose FEIS's are available but not in model.

Region	Forest
1	Flathead
2	Shoshone
3	Coronado, Gila, Lincoln
4	Ashley, Dixie, Manti LaSal, Uinta[1]
8	Cherokee, Ouachita, Texas, Florida
9	Chequamegon, Green Mountain, Nicolet, Ottawa, Shawnee

[1] *The Uinta National Forest FEIS was available at the time the Region 4 model was built but there are no scheduled production data in this FEIS, nor are any available from other planning records.*

Production Constraint Rows

The outputs (except cost) collected in the accounting columns are transferred to the production constraint rows. These rows constrain the outputs in solution to meet specified targets. The production constraints are assigned by means of adding "bounds" data to the LP problem input data. A specified target value (RHS) is assigned each output along with coding that designates the values as either a lower bound (LO, meaning $\geq$ type) or upper bound (UP, meaning $\leq$ type) constraint on physical production.

Data Storage

After the homogenous data sets were completed for each forest in a region, the next step involved storing this regional forest production data in a data file on the Sperry Univac 1100 computer system at the Fort Collins Computer Center (FCCC).

Table 8.–Data file with production data and computer code formulation of LP problem for Region 4.

1.	NAME		RPAR4			
2.	ROWS					
3.	E	REC1				
4.	E	REC2				
5.	E	REC3				
6.	E	REC4				
7.	E	REC5				
8.	E	HAB1				
9.	E	HAB2				
10.	E	HAB3				
11.	E	HAB4				
12.	E	HAB5				
13.	E	ELK1				
14.	E	ELK2				
15.	E	ELK3				
16.	E	ELK4				
17.	E	ELK5				
18.	E	RNG1				
19.	E	RNG2				
20.	E	RNG3				
21.	E	RNG4				
22.	E	RNG5				
23.	E	TMBR1				
24.	E	TMBR2				
25.	E	TMBR3				
26.	E	TMBR4				
27.	E	TMBR5				
28.	E	WTR1				
29.	E	WTR2				
30.	E	WTR3				
31.	E	WTR4				
32.	E	WTR5				
33.	E	SDMT1				
34.	E	SDMT2				
35.	E	SDMT3				
36.	E	SDMT4				
37.	E	SDMT5				
38.	E	COST1				
39.	E	COST2				
40.	E	COST3				
41.	E	COST4				
42.	E	COST5				
43.	N	MINOBJ				
44.	E	ASHLEY				
45.	E	CARIBOU				
46.	E	CHALLIS				
47.	E	DIXIE				
48.	E	FISHLAKE				
49.	E	HUMBOLDT				
50.	E	MANTI				
51.	E	PAYETTE				
52.	E	SALMON				
53.	E	SAWTOOTH				
54.	E	TARGHEE				
55.	E	TOIYABE				
56.	E	WASATCH				
57.	E	BRIDGER				
58.	COLUMNS					
59.	R4/1/1	REC1	992.	REC2	1141.	
60.	R4/1/1	REC3	1287.	REC4	1434.	
61.	R4/1/1	REC5	1579.	HAB1	925.	
62.	R4/1/1	HAB2	925.	HAB3	925.	
63.	R4/1/1	HAB4	925.	HAB5	925.	
64.	R4/1/1	ELK1	5800.	ELK2	5900.	

(Continued)

Table 8.--(continued).

65.	R4/1/1	ELK3	5800.	ELK4	5700.
66.	R4/1/1	ELK5	5500.	RNG1	77.
67.	R4/1/1	RNG2	80.	RNG3	82.
68.	R4/1/1	RNG4	83.	RNG5	84.
69.	R4/1/1	TMBR1	13.8	TMBR2	12.
70.	R4/1/1	TMBR3	11.7	TMBR4	10.5
71.	R4/1/1	TMBR5	8.6	WTR1	960.
72.	R4/1/1	WTR2	972.	WTR3	982.
73.	R4/1/1	WTR4	989.	WTR5	993.
74.	R4/1/1	SDMT1	32.	SDMT2	33.
75.	R4/1/1	SDMT3	35.	SDMT4	38.
76.	R4/1/1	SDMT5	36.	COST1	4.91
77.	R4/1/1	COST2	5.73	COST3	6.78
78.	R4/1/1	COST4	6.71	COST5	6.93
79.	R4/1/1	ASHLEY	1.		
.					
.					
.					
3061.	R4/14/9	BRIDGER	1.		
3062.	R4/14/10	REC1	1843.8	REC2	2513.9
3063.	R4/14/10	REC3	3098.5	REC4	3831.0
3064.	R4/14/10	REC5	4453.6	HAB1	1008.
3065.	R4/14/10	HAB2	1000.	HAB3	1020.
3066.	R4/14/10	HAB4	1117.	HAB5	1406.
3067.	R4/14/10	ELK1	1781.0	ELK2	18725.
3068.	R4/14/10	ELK3	19650.	ELK4	20575.
3069.	R4/14/10	ELK5	21550.	RNG1	225.2
3070.	R4/14/10	RNG2	257.5	RNG3	258.9
3071.	R4/14/10	RNG4	260.5	RNG5	264.0
3072.	R4/14/10	TMBR1	8.54	TMBR2	11.44
3073.	R4/14/10	TMBR3	15.06	TMBR4	15.06
3074.	R4/14/10	TMBR5	15.06	WTR1	5728.9
3075.	R4/14/10	WTR2	5735.3	WTR3	5740.5
3076.	R4/14/10	WTR4	5743.1	WTR5	5744.0
3077.	R4/14/10	SDMT1	198.05	SDMT2	198.42
3078.	R4/14/10	SDMT3	198.31	SDMT4	198.57
3079.	R4/14/10	SDMT5	198.12	COST1	4.95
3080.	R4/14/10	COST2	5.56	COST3	6.01
3081.	R4/14/10	COST4	6.18	COST5	6.48
3082.	R4/14/10	BRIDGER	1.		
3083.	REC1P	REC1	-1.		
3084.	REC2P	REC2	-1.		
3085.	REC3P	REC3	-1.		
3086.	REC4P	REC4	-1.		
3087.	REC5P	REC5	-1.		
3088.	HAB1P	HAB1	-1.		
3089.	HAB2P	HAB2	-1.		
3090.	HAB3P	HAB3	-1.		
3091.	HAB4P	HAB4	-1.		
3092.	HAB5P	HAB5	-1.		
3093.	ELK1P	ELK1	-1.		
3094.	ELK2P	ELK2	-1.		
3095.	ELK3P	ELK3	-1.		
3096.	ELK4P	ELK4	-1.		
3097.	ELK5P	ELK5	-1.		
3098.	RNG1P	RNG1	-1.		
3099.	RNG2P	RNG2	-1.		
3100.	RNG3P	RNG3	-1.		
3101.	RNG4P	RNG4	-1.		
3102.	RNG5P	RNG5	-1.		
3103.	TMBR1P	TMBR1	-1.		
3104.	TMBR2P	TMBR2	-1.		
3105.	TMBR3P	TMBR3	-1.		
3016.	TMBR4P	TMBR4	-1.		

(Continued)

Table 8.--(continued).

3107.		TMBR5P	TMBR5	-1.		
3108.		WTR1P	WTR1	-1.		
3109.		WTR2P	WTR2	-1.		
3110.		WTR3P	WTR3	-1.		
3111.		WTR4P	WTR4	-1.		
3112.		WTR5P	WTR5	-1.		
3113.		SDMT1P	SDMT1	-1.		
3114.		SDMT2P	SDMT2	-1.		
3115.		SDMT3P	SDMT3	-1.		
3116.		SDMT4P	SDMT4	-1.		
3117.		SDMT5P	SDMT5	-1.		
3118.		COST1P	COST1	-1.	MINOBJ	1.
3119.		COST2P	COST2	-1.	MINOBJ	1.
3120.		COST3P	COST3	-1.	MINOBJ	1.
3121.		COST4P	COST4	-1.	MINOBJ	1.
3122.		COST5P	COST5	-1.	MINOBJ	1.
3123.	RHS					
3124.		RHS1	REC1	0.	REC2	0.
3125.		RHS1	REC3	0.	REC4	0.
3126.		RHS1	REC5	0.	HAB1	0.
3127.		RHS1	HAB2	0.	HAB3	0.
3128.		RHS1	HAB4	0.	HAB5	0.
3129.		RHS1	ELK1	0.	ELK2	0.
3130.		RHS1	ELK3	0.	ELK4	0.
3131.		RHS1	ELK5	0.	RNG1	0.
3132.		RHS1	RNG2	0.	RNG3	0.
3133.		RHS1	RNG4	0.	RNG5	0.
3134.		RHS1	TMBR1	0.	TMBR2	0.
3135.		RHS1	TMBR3	0.	TMBR4	0.
3136.		RHS1	TMBR5.	0.	WTR1	0.
3137.		RHS1	WTR2	0.	WTR3	0.
3138.		RHS1	WTR4	0.	WTR5	0.
3139.		RHS1	SDMT1	0.	SDMT2	0.
3140.		RHS1	SDMT3	0.	SDMT4	0.
3141.		RHS1	SDMT5	0.	COST1	0.
3142.		RHS1	COST2	0.	COST3	0.
3143.		RHS1	COST4	0.	COST5	0.
3144.		RHS1	ASHLEY	1.	CARIBOU	1.
3145.		RHS1	CHALLIS	1.	DIXIE	1.
3146.		RHS1	FISHLAKE	1.	HUMBOLDT	1.
3147.		RHS1	MANTI	1.	PAYETTE	1.
3148.		RHS1	SALMON	1.	SAWTOOTH	1.
3149.		RHS1	TARGHEE	1.	TOIYABE	1.
3150.		RHS1	WASATCH	1.	BRIDGER	1.
3151.	BOUNDS					
3152.		LO BOUNDS1		REC1P	17230.73	
3153.		LO BOUNDS1		REC2P	17230.73	
3154.		LO BOUNDS1		REC3P	17230.73	
3155.		LO BOUNDS1		REC4P	17230.73	
3156.		LO BOUNDS1		REC5P	17230.73	
3157.		LO BOUNDS1		HAB1P	18737.	
3158.		LO BOUNDS1		HAB2P	18737.	
3159.		LO BOUNDS1		HAB3P	18737.	
3160.		LO BOUNDS1		HAB4P	18737.	
3161.		LO BOUNDS1		HAB5P	18737.	
3162.		LO BOUNDS1		ELK1P	78817.	
3163.		LO BOUNDS1		ELK2P	78817.	
3164.		LO BOUNDS1		ELK3P	78817.	
3165.		LO BOUNDS1		ELK4P	78817.	
3166.		LO BOUNDS1		ELK5P	78817.	
3167.		LO BOUNDS1		RNG1P	2045.92	
3168.		LO BOUNDS1		RNG2P	2045.92	
3169.		LO BOUNDS1		RNG3P	2045.92	
3170.		LO BOUNDS1		RNG4P	2045.92	
3171.		LO BOUNDS1		RNG5P	2045.92	
3172.		LO BOUNDS1		TMBR1P	102.99	
3173.		LO BOUNDS1		TMBR2P	102.99	
3174.		LO BOUNDS1		TMBR3P	102.99	
3175.		LO BOUNDS1		TMBR4P	102.99	
3176.		LO BOUNDS1		TMBR5P	102.99	
3177.		LO BOUNDS1		WTR1P	23381.64	
3178.		LO BOUNDS1		WTR2P	23381.64	
3179.		LO BOUNDS1		WTR3P	23381.64	
3180.		LO BOUNDS1		WTR4P	23381.64	
3181.		LO BOUNDS1		WTR5P	23381.64	
3182.	ENDATA					

(Continued)

These data files were not used simply for data storage, but constituted a computer code formulation of the upper level LP. This required a specified data image format specified by the Functional Mathematical Programming System (FMPS) in the Sperry Univac 1100 computer system.

Table 8 shows a data file with a computer code formulation for Region 4. Note that the LP problem data are organized into 4 chapters--rows, columns, right hand sides (RHS), and bounds. The rows chapter defines the rows that will be used in the LP and specifies the type of constraint. The Es indicate row type equality, while the N indicates a nonconstraining row to be used as the objective function. The columns chapter serves two functions. The first function is to define the columns in the matrix, and the second function is to enter the technical coefficients into the matrix (this portion of table 8 is truncated to save space). The coefficients are entered into the file directly from the homogenous recording matrixes. The accounting variables are also entered in this input chapter. Note that the costs are linked to the objective function here. The RHS chapter specifies the right hand side values of the accounting and 0-1 constraint rows. Finally, the bounds chapter assigns target levels for each output. Note that technical coefficients with a value of zero need not be entered in the appropriate chapter.

Table 9 illustrates an initial coded matrix for the LP problem of interest in this analysis (this example utilizes Region 4 data truncated to the first two alternatives for the first forest and the last two alternatives for the last (14th) forest to save space). The A's in the A-matrix represent the production coefficients. Note that no bounds are designated for costs, because they serve as the objective function. Also note that sediment yield is constrained by upper bounds, while all other outputs have lower bounds. The remainder of the matrix has either zero (represented by blanks) or unitary coefficients (with a negative operator in the case of the accounting columns) as described previously.

DESCRIPTION OF SOLUTION OUTPUT

The LP problem is formulated so the solution results in the selection of one alternative (or the partial selection of several alternatives, the combination of which satisfies the 0-1 constraints), and its (their) associated vector of outputs and cost, from each forest planning unit. This selection typically depends

Table 9.--Illustration of an initially coded LP problem matrix.

	R4/1/1	R4/1/2	...	R4/14/9	R4/14/10	REC1P	REC2P	REC3P	REC4P	REC5P	HAB1P	HAB2P	HAB3P	HAB4P	HAB5P	ELK1P	ELK2P	ELK3P	ELK4P	ELK5P	RNG1P	RNG2P	RNG3P	RNG4P	RNG5P	TMBR1P	TMBR2P	TMBR3P	TMBR4P	TMBR5P	WTR1P	WTR2P	WTR3P	WTR4P	WTR5P	SDMT1P	SDMT2P	SDMT3P	SDMT4P	SDMT5P	COST1P	COST2P	COST3P	COST4P	COST5P	RHS1
LOWER BOUND						L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L											
UPPER BOUND																																				U	U	U	U	U						
REC1	A	A		A	A	-1																																								0
REC2	A	A		A	A		-1																																							0
REC3	A	A		A	A			-1																																						0
REC4	A	A		A	A				-1																																					0
REC5	A	A		A	A					-1																																				0
HAB1	A	A		A	A						-1																																			0
HAB2	A	A		A	A							-1																																		0
HAB3	A	A		A	A								-1																																	0
HAB4	A	A		A	A									-1																																0
HAB5	A	A		A	A										-1																															0
ELK1	A	A		A	A											-1																														0
ELK2	A	A		A	A												-1																													0
ELK3	A	A		A	A													-1																												0
ELK4	A	A		A	A														-1																											0
ELK5	A	A		A	A															-1																										0
RNG1	A	A		A	A																-1																									0
RNG2	A	A		A	A																	-1																								0
RNG3	A	A		A	A																		-1																							0
RNG4	A	A		A	A																			-1																						0
RNG5	A	A		A	A																				-1																					0
TMBR1	A	A		A	A																					-1																				0
TMBR2	A	A		A	A																						-1																			0
TMBR3	A	A		A	A																							-1																		0
TMBR4	A	A		A	A																								-1																	0
TMBR5	A	A		A	A																									-1																0
WTR1	A	A		A	A																										-1															0
WTR2	A	A		A	A																											-1														0
WTR3	A	A		A	A																												-1													0
WTR4	A	A		A	A																													-1												0
WTR5	A	A		A	A																														-1											0
SDMT1	A	A		A	A																															-1										0
SDMT2	A	A		A	A																																-1									0
SDMT3	A	A		A	A																																	-1								0
SDMT4	A	A		A	A																																		-1							0
SDMT5	A	A		A	A																																			-1						0
COST1	A	A		A	A																																				-1					0
COST2	A	A		A	A																																					-1				0
COST3	A	A		A	A																																						-1			0
COST4	A	A		A	A																																							-1		0
COST5	A	A		A	A																																								-1	0
MINOBJ																																									1	1	1	1	1	N
ASHLEY	1	1																																												1
BRIDGER-TETON				1	1																																									1

upon which combination of alternatives minimizes aggregate costs subject to constraints on the aggregate production of outputs. If it is not possible to satisfy all of the constraints, there is no feasible solution to the problem, and it must be reformulated by restating the constraints. A solution is feasible if all constraints can be satisfied, and is optimal when it has the most favorable value of the objective function (the minimum cost in typical cases).

The LP solution output emanates from the FMPS software, and follows the format documented for that LP solution package. The principal solution information of interest would typically be the value of the variables in solution, and the output shadow prices. In this format, a "column activity" displays the value of the variables selected to be in the solution. The decision variables that are rejected (not in the solution) have a value of zero. The column labeled "reduced cost" in the solution output represents the shadow price of the specified variables. The shadow price for a product measures the marginal contribution of that output to the value of the objective function, that is, the rate at which the objective function (minimum cost) could be decreased by decreasing the constraint on the output by one unit (increasing the constraint in the case of sediment output) while holding all other variable constraints constant. However, there is a limited range within which a constraint on a particular variable can be changed before the solution will result in a different basis--implying that it may have a greater effect on the objective function than is indicated by the shadow price. The relative ranges for this kind of parametric change for all of the variables can be determined using the FMPS algorithm.

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APPENDIX 1

Study Notes Documenting Homogenous Data Set for Bridger-Teton National Forest

I. Nonhomogenous Data Set and Deficiencies
  A. Alternatives
    1. 10 primary and 2 benchmark.
  B. REC
    1. Dispersed recreation fully scheduled for primary and benchmark alternatives-tables II-1 and B-III-2.
      a. includes WFUD's - table II-17, page II-125.
      b. excludes wilderness RVD's - table II-17, page II-125.
    2. Wilderness recreation fully scheduled for primary and benchmark alternatives-tables II-1 and B-III-2.
    3. Total dispersed recreation = dispersed + wilderness
  C. HAB
    1. Fully scheduled for all primary and benchmark alternatives - tables II-1 and B-III-2.
  D. ELK
    1. Reported only for 5th period of primary alternatives - bargraph on page II-130.
  E. RNG
    1. Fully scheduled for all primary and benchmark alternatives - tables II-1 and B-III-2.
  F. TMBR
    1. Allowable sale fully scheduled for primary and benchmark alternatives in CF - tables II-1 and B-III-2.
    2. Fuelwood and other products fully scheduled for primary and benchmark alternatives in BF - tables II-1 and B-III-2.
      a. BF to CF conversion ratios not reported.
  G. WTR
    1. Total water yield not reported.
    2. Water yield meeting quality goals fully scheduled for primary and benchmark alternatives - tables II-1 and B-III-2.
    3. Increased water yield over natural fully scheduled for primary and benchmark alternatives - tables II-1 and B-III-2.
    4. It is implicit in table II-1 (see page II-37) that natural yield is 5726.1 MAcFt/yr and that total water yield is equal to water meeting quality goals.
    5. Can either use water meeting quality goals or add increase over natural to natural yield.
      a. for example, using period #1 of alternative #1.
        1) water meeting quality goals = 5740.30 MAcFt or
        2) increase over natural = 14.2 MAcFt so 14.2 MAcFt + 5726.1 MAcFt = 5740.30 MAcFt
  H. SDMT
    1. Sediment yield not reported.
    2. Natural sediment rate reported = 195,000 tons/yr - page IV-65.
    3. Text indicated sediment yield scheduled in other planning records.
  I. COST
    1. Costs fully scheduled for primary and benchmark alternatives in 82$ - tables II-1-B and B-III-2B.
    2. Allocated funds not mentioned in EIS.
    3. Convert 82$ to 78$.
      a. use implicit price deflator (1972=100).
      b. for example, for period #1 of alternative #1.
        1) 1982=207.38 and 1978=150.42
        2) so deflator is $\frac{150.42}{207.38}$
        3) and 10.89 MM1982$ x $\frac{150.42}{207.38}$ = 7.90 MM1978$

II. Data Provided by Forest
  A. Forest Contact Persons - Carl Pence, Paul Arnt
    1. Phone # 307-733-2752
    2. Initial contact - 10/28/86
    3. Forest provided data - 11/12/86
  B. ELK
    1. 1st period primary alternatives provided by forest.
      a. 17,800 elk across all primary alternatives.
      b. Periods 2, 3, and 4 of primary alternatives and all periods, benchmarks unavailable.
  C. TMBR
    1. Forest provided BF to CF conversion ratios.
      a. Fuelwood - 4.86
      b. Other products - 1.00
  D. SDMT
    1. Forest provided schedule of increases over natural yield for primary alternatives - Mtons/year.
      a. Alternatives

Period	1	2	3	4	5	6	7	8	9	10
1	17.83	17.83	7.24	6.80	6.80	3.63	3.33	2.02	3.50	3.05
2	18.02	18.02	8.15	6.50	6.50	3.25	3.53	2.10	3.07	3.42
3	18.62	18.62	7.41	6.43	6.43	3.22	3.38	1.90	2.96	3.31
4	20.55	20.55	7.65	6.01	6.01	3.46	3.64	2.16	3.11	3.57
5	19.73	19.73	7.23	5.38	5.38	3.03	3.18	1.92	2.92	3.12

  E. COST
    1. Allocated funds are insignificant.

III. Homogenous Data Set Completed

A. ELK

1. Interpolate using periods 1 and 5 data to estimate data for periods 2, 3, and 4 of the primary alternatives.
   a. For example, using alternative #1.
      1) 1st = 17,800 and 5th = 13,000
      2) so (17,800 - 13,000) / 4 = 1200
      3) and 2nd = 17,800 - 1200 = 16,600
         3rd = 16,600 - 1200 = 15,400
         4th = 15,400 - 1200 = 14,200
         5th = 14,200 - 1200 = 13,000

B. TMBR

1. Convert fuelwood and other products to CF and aggregate all timber outputs to get total timber.
   a. For example, using period #1 of alternative #1.
      1) Other products = 16.5 MMBF and 16.5 MMBF / 1.00 = 16.50 MMCF
      2) Fuelwood = 48.2 MMBF and 48.2 MMBF / 4.86 = 9.92 MMCF
      3) Allowable sale = 16.80 MMCF
      4) Total timber in period #1 of alternative #1 = 43.22 MMCF

C. Alternatives

1. 10 primary alternatives.
   a. Benchmark alternatives BM-1 and BM-2 eliminated from analysis:
      1) Elk and sediment unscheduled and unavailable.
      2) No logical method for estimating elk with data available.

APPENDIX 2

Examples of Distinct Methodologies for Deriving and Estimating Missing Outputs

Examples of Distinct Methodologies for Deriving and Estimating Dispersed Recreation

I. Clearwater NF

A. In Region 1, dispersed recreation was recorded in two categories: motorized and nonmotorized. These categories were aggregated from the Recreation Opportunity Spectrum (ROS) classifications (roaded natural, semiprimitive motorized, semiprimitive nonmotorized, and primitive or wilderness) generally reported in this region.

B. Semiprimitive motorized and semiprimitive nonmotorized dispersed recreation were combined into one semiprimitive category for the Clearwater. The disaggregation of this category was not available.

C. Use a neighboring forest, the Nezperce, to estimate the disaggregation of this category into motorized and nonmotorized components.

1. On the Nezperce, semiprimitive motorized dispersed recreation represents approximately 90% of total semiprimitive dispersed recreation across all alternatives and decades. Use this percentage to estimate the disaggregation of semiprimitive dispersed recreation into motorized and nonmotorized semiprimitive dispersed recreation across all alternatives and decades for the Clearwater.

2. Then aggregate roaded natural and semiprimitive motorized to obtain total motorized dispersed recreation (RECM) and semiprimitive nonmotorized and wilderness to obtain total nonmotorized dispersed recreation (RECNM).

II. Beaverhead NF

A. Semiprimitive nonmotorized, semiprimitive motorized, and roaded natural dispersed recreation were labeled Type 1, Type II, and Type III dispersed recreation, respectively, on this forest.

B. Aggregate Type I and wilderness recreation into the total nonmotorized dispersed component and Type II and Type III into the total motorized dispersed component.

III. Black Hills NF

A. Wilderness RVD's were reported.

B. Dispersed RVD's were reported (table IV-33). The table did not indicate if wilderness RVD's were included in this figure.

1. The Forest indicated that wilderness RVD's were included in the dispersed recreation reported in table IV-33.

IV. Numerous Forests

A. Wildlife and fish user days (WFUD's) were often reported separately in the EIS in addition to the category called dispersed recreation. However, it was not always made explicit as to whether or not WFUD's were included in the dispersed recreation category reported. In such cases, the forest would be contacted to supply that information.

B. Wilderness RVD's were usually reported separately and not included in the dispersed recreation category reported.

1. Wilderness RVD's would then be added to dispersed recreation to obtain total dispersed recreation.

V. George Washington NF

A. Dispersed recreation, wilderness RVD's, and WFUD's were reported separately in tables B-16 of original DEIS and II-IA of supplement.
B. Forest personnel indicated that wilderness RVD's and WFUD's were included in the dispersed recreation figure reported in these tables.

VI. Monongahela NF

A. Total recreation was reported by ROS class. No distinction was made between developed and dispersed recreation (page B-191 to B-194).
B. The Forest indicated semiprimitive motorized and roaded natural contain both developed and dispersed recreation in the following proportions:

Period	Dispersed	Developed
1	67%	33%
2 through 5	68%	32%

C. The Forest indicated rural is all developed and semiprimitive nonmotorized is all dispersed.

Examples of Distinct Methodologies for Deriving and Estimating Wildlife Habitat Improvement

I. Beaverhead NF

A. HAB was reported in dollars but not available in acres.
B. Objectives outlined in proposed plan call for 3,319 acre equivalents of habitat improvements per year.
C. Reported annual cost of habitat improvement for proposed alternative is $14,400.
D. Use cost and acres from proposed alternative and scheduled HAB dollars to estimate acres of habitat improvements for all other alternatives.
   1. 3,319 acres / $14,400 = .23 acre/$
   2. Multiply HAB schedule in $ by .23 to get estimates for scheduled acres.

II. Custer NF

A. HAB was reported only for periods 1, 3, and 5 but not available for periods 2 and 4.
B. Interpolate to estimate for periods 2 and 4 (the average of periods 1 and 3 and 3 and 5 respectively).

III. Numerous Forests

A. HAB was often reported on a 50-year average annual basis and recorded likewise in this study if neither additional data nor a logical method for estimating decadal differences were available.

IV. Prescott NF

A. Wildlife "projects" were reported in $ for the first and fifth periods.
B. The Forest provided cost figure of $40/acre of wildlife habitat improvement. No other data was available.
C. Convert the scheduled $ to acres by dividing by $40/acre and then interpolate between periods 1 and 5 to estimate for periods 2, 3, and 4.

V. Chippewa NF

A. HAB was scheduled only for alternative #3.
B. No other data was available.
C. Wildlife benefits in $ were scheduled for all alternatives.
D. Apply the decadal HAB/wildlife benefits ratio for alternative #3 to the schedule of wildlife benefits for all other alternatives to estimate their HAB.
E. For example, in period 1 of alternative #3, HAB/$ benefits = 4090/2.86 = 1430.07.
   1. Since $ benefits = 2.73 for period 1 of alternative #2, then 2.73 x 1430.07 = 3904 acres of wildlife habitat improvements for this alternative and period.

Examples of Distinct Methodologies for Deriving and Estimating Elk.

I. Grand Mesa, Uncompahgre, & Gunnison NF

A. Total big game potential for deer and elk was scheduled.
B. The current percentage split of 74% and 26% respectively was reported.
C. The forest indicated the same proportional split exists across all alternatives and decades.

II. Shoshone NF

A. Elk was not reported. No other data were available from the forest.
B. Forage reserved for wildlife was scheduled as cattle animal unit months (CAUM) in table IV-9, pg. IV-29.
C. Current populations (1983) for big game species are reported (elk, deer, sheep, moose, antelope, goat) in table II-13, pg. III-36.
D. CAUM equivalents for elk, deer, and sheep were reported.
E. Use the schedule of CAUM's, current wildlife populations, and CAUM equivalents to estimate elk.
F. Current wildlife populations and % of total are:

Animal	1983 Population	% Of Total Big Game
Elk	15,700	45
Deer	13,450	38
Sheep	3,890	11
Moose	855	2
Antelope	1,210	3
Goat	100	1
Total	35,205	100%

G. CAUM equivalents are: 2 elk, 4 deer, and 5 sheep.
   1. Assume the same CAUM equivalents for moose and antelope as for elk and deer, respectively.

H. Assuming constant 1983 percentage composition of big game species across all periods for all alternatives, use reserved forage schedule and CAUM equivalents to estimate the schedule of elk populations.

I. For example, for period 1 of alternative A, reserved CAUM's = 39,400.
   1. If x = total big game, then

      $$39{,}400 = X\left(\frac{.45}{2} + \frac{.38}{4} + \frac{.11}{5} + \frac{.02}{2} + \frac{.03}{4} + \frac{.01}{5}\right)$$

      where the numerators are the % of total big game species for elk, deer, sheep, moose, antelope, and goat, respectively, and the denominators are CAUM equivalents for those same respective game species.
   2. Thus, X=108,990 animals and reserved forage can accommodate .45(108,990) = 49,045 elk.
   3. However, since 1983 elk populations are close to the objective for period 1 (15,075 elk), use the ratio of 1983 CAUM equivalents to the CAUM forage reserve in period 1 of the no action alternative across all periods and alternatives to estimate elk populations.
   4. Thus, $\frac{15{,}700}{2} + \frac{13{,}450}{4} + \frac{3890}{5} + \frac{855}{2} + \frac{1210}{4} + \frac{100}{5} = 12{,}740.5$

      CAUM equivalents for 1983.
   5. Then 12,740.5 (CAUM equivalents) / 39,400 (CAUM capacity) = 32%.
   6. Apply this ratio across all periods and alternatives.
   7. Thus, for period 1, alternative A, .32 x 49,045 = 15,695 elk.

III. Coconino NF
   A. Elk was not reported.
   B. The forest provided elk numbers for periods 1 and 5 across all alternatives.
   C. Interpolate to estimate for periods 2, 3, and 4.

IV. Gila NF
   A. Elk was not reported and not available.
   B. The forest provided estimations, based on habitat components, for the first and fifth periods.
      1. The forest indicated the second period for alternatives with increasing elk would be 7000 animals (except for alternative B), then interpolate from there.
      2. The forest indicated that for alternatives with decreasing elk, periods 3 and 4 are the same as period 5. Interpolate to get period 2.

V. Lincoln NF
   A. Elk was not reported.
   B. The forest indicated that elk was recently reintroduced on the forest.
      1. The forest will try to maintain a viable population of approximately 350 animals.
   C. The percent increase in habitat for indicator species (includes elk) was reported for the planning horizon by alternative in table 58, page 139.
   D. Use table 58 and initial viable population of 350 animals to estimate the schedule for elk.
   E. For an example, alternatives B and C are utilized.
      1. There is no increase in habitat in alternative B, so elk population is estimated to remain at 350 animals over all periods.
      2. There is a 10% increase in habitat in alternative C, so the elk population is estimated at 385 animals (350 + .10 x 350) over all periods.

Examples of Distinct Methodologies for Estimating Deer

I. Tahoe NF
   A. The low and high range for deer was reported by alternative.
   B. The forest indicated that these figures represented first and fifth period populations respectively. Periods 2, 3, and 4 were not available.
   C. Interpolate between periods 1 and 5 to estimate deer populations for periods 2, 3, and 4.

II. Florida NF
   A. Deer was not scheduled. Current population, optimum population, and minimum population was reported.
   B. A Deer habitat capability index was scheduled for alternatives 2 and 10 and provided by the forest.
      1. The forest also provided the following information. When the index = 100, deer population is 12,200. A maximum index number of 130 is equivalent to an optimum deer population of 24,400. A minimum index number of 75 is equivalent to a minimum deer population of 6,250.
   C. Use the habitat capability index (Y) and reforestation and thinning acres (X) for alternatives 2 and 10 to calculate a regression equation.
      1. For Y=mX+b
         m=24.9
         b=81.53
         r=.59
         and Y=24.9X + 81.53
   D. Use the regression equation above with reforestation and thinning acres from all other alternatives (as independent variable, X) to estimate a fully scheduled habitat capability index.
   E. Then use the estimated capability index along with the data equating current, optimum, and minimum deer populations to specified index numbers to estimate the full schedule of deer populations.
   F. For example, for alternative 1, the habitat capability index numbers estimated using the regression equation are:

Period	Index #
1	92
2	97
3	102
4	97
5	94

1. Since 100-75 = 25 index points and 12,200 - 6250 = 5950 deer, there are 238 deer/index point below 100 (5980 / 25 = 238).
2. Similarly, since 130-100 = 30 index points and 24,400 - 12,200 = 12,200 deer, there are 407 deer/ index point above 100 (12,200 / 30 = 407).
3. Then, the final calculations in the estimation of deer numbers are:

Period			# Deer
1	12,200-[(100-92)x238]	=	10,296
2	12,200-[(100-97)x238]	=	11,486
3	12,200+[(102-100)x407]	=	13,014
4	12,200+[(100-97)x238]	=	11,486
5	12,200+[(100-94)x238]	=	10,712

Examples of Distinct Methodologies for Deriving or Estimating Fish

I. Idaho Panhandle NF
   A. Fish was reported for periods 1, 2, and 5 but not available for periods 3 and 4.
   B. Calculate a regression equation for each alternative using available fish data (periods 1, 2, and 5) and the analagous sediment yields.
   C. Estimate missing fish data using these equations and sediment from periods 3 and 4 as the independent variable x.
   D. For example, for alternative 1, the regression is Y = -1.8276X + 3099.03 and r = -.99.
      1. Applying sediment yields to this regression, fish is estimated for periods 3 and 4 as follows:

Period			Mfish
3	-1.8276(261.7)+3099.03	=	2621
4	-1.8276(196.6)+3099.03	=	2740

II. Custer NF
   A. Fish was reported for the first, third, and fifth periods but not available for the second and third period.
   B. Interpolate to estimate fish in second and third periods.

III. Numerous Forests
   A. Forests often reported several categories of fish separately.
   B. These categories were simply aggregated to obtain total fish potential.

Examples of Distinct Methodologies for Estimating Range

I. Helena NF
   A. Range was reported for all periods except the fourth, which was not available.
   B. Estimate the fourth period by interpolation.

II. Regions 8 and 9
   A. If range was not mentioned in the EIS's, it was recorded as -0- across all periods and alternatives.
   B. Several forest EIS's indicated range was insignificant and it was not reported.
      1. Range was recorded at -0- across all periods and alternatives in these cases.

Examples of Distinct Methodologies for Deriving and Estimating Timber

I. Custer NF
   A. Timber was reported for periods 1, 3, and 5 but unavailable for periods 2 and 4.
   B. Estimate for periods 2 and 4 by interpolation.

II. Numerous Forests
   A. Other forest timber outputs such as fuelwood, posts and poles, and biomass were often reported in addition to allowable sale, base harvest or net merchantable.
      1. These were simply aggregated, after any necessary conversion to common reporting units, to derive a total timber production schedule.

III. Cibola NF
   A. Fuelwood was reported in BF but the conversion ratio (to CF) was not available.
   B. Sawtimber and other products were reported in BF and CF.
      1. The conversion for these timber outputs is approximately 3.66:1 based on conversion calculations from a sampling of the reported data.
      2. Use this ratio as the estimate for fuelwood volume.

IV. Caribou NF
   A. Fuelwood was reported in cords but the ratio to convert to CF was not available.
   B. Use the conversion ratio from Manti-LaSal, 1 cord = 84 CF.

V. Inyo NF
   A. Fuelwood was reported in cords but the conversion ratio was not available.
   B. The cords to CF conversion ratio for fuelwood in the Pacific Coast Region is reported as 86.7 CF/cord in "An Analysis of the Timber Situation in the United States 1952-2030" (USDA, Forest Service, 1982).
   C. This conversion ratio was used for Regions 5 and 6 unless otherwise provided by forests.

VI. Stanislaus NF
   A. Biomass was reported in tons.
   B. The forest suggested using the same conversion as on the Lassen, 25LB/CF or 80 CF/ton.

VII. Francis Marion NF
   A. Fuelwood was reported by alternative as 50 year totals. A schedule was not available.
   B. The forest indicated that a good fuelwood schedule estimate would be to proportion fuelwood totals with the allowable sale schedule.

VIII. Wayne NF
   A. Total harvest was reported in BF but a conversion to CF was not available.
   B. Use the conversion for LTSY which was reported at 3.54 MMCF/yr = 20.7 MMBF/year or 5.85:1.

Examples of Distinct Methodologies for Deriving and Estimating Water Yield

I. Clearwater NF
   A. Water yield was not reported.
   B. Estimate water yield using a regression equation with allowable sale and water yield data from a neighboring forest, the Nezperce.
      1. Use alternatives D, E, and G from the Nezperce since these display a range in allowable sale closest to that of the Clearwater.
      2. Transform the allowable sale data to allowable sale equivalents to account for carryover effects.
   C. For example, the equivalents for alternative G1 are:

Period	Allowable sale	Allowable sale equivalents
1	21.7	97.1
2	27.2	257.7
3	33.9	472.3
4	42.4	682.1
5	53.0	891.9

      1. Using coefficients developed from the 75%, 66%, 50%, and 33% water yield carryover effects, the above equivalents were calculated as follows:
         4.375 x 21.7 = 97.1
         4.375 x 27.2 + 7.095 x 21.7 = 257.7
         4.375 x 33.9 + 7.095 x 27.2 + 5.88 x 21.7 = 472.3
         4.375 x 42.4 + 7.095 x 33.9 + 5.88 x 27.2 + 4.325 x 21.7 = 682.1
         4.375 x 53.0 + 7.095 x 42.4 + 5.88 x 33.9 + 4.235 x 27.2 + 1.815 x 21.7 = 891.9
      2. The regression equation using this Nezperce data is Y = .047 X + 41.79.
   D. Estimate increase in water yields for the Clearwater using this regression equation.
   E. For example, the allowable sale equivalents for alternative A from the Clearwater are:

Period	Allowable sale	Allowable sale equivalents
1	36.9	161.4
2	44.3	455.6
3	53.1	763.6
4	63.8	1072.6
5	76.5	1354.2

      1. Then solve the regression Y = .047 X + 41.79 where X is the independent variables (allowable sale equivalents) and Y is the dependent variable (increase in water yield).

Period	m	X	+	b	=	Y (increased) (yield)
1	.047	(161.4)	+	41.79	=	49.4
2	.047	(455.6)	+	41.79	=	63.2
3	.047	(763.3)	+	41.79	=	77.7
4	.047	(1072.6)	+	41.79	=	92.2
5	.047	(1354.2)	+	41.79	=	105.4

   F. Add the increase to base water yield to get total water yield.
   G. First estimate the base water yield for the Clearwater.
      1. The Nezperce forest area = 2,218,040 acres.
      2. The Clearwater forest area = 1,837,116 acres.
      3. Thus, the Clearwater equals 82.83% (1,837,116 / 2,218,040) of the Nezperce.
      4. The Nezperce base water yield = 3600 MAcFt.
      5. The estimated base water yield for the Clearwater is thus 2981.88 MAcFt (.8283 x 3600 MAcFt).
   H. Total water yield for alternative A from the Clearwater can now be estimated as follows:

Period	Increased yield	+	Base	=	Total yield (MAcFt)
1	49.4	+	2981.88	=	3031.3
2	63.2	+	2981.88	=	3045.1
3	77.7	+	2981.88	=	3059.6
4	92.2	+	2981.88	=	3074.1
5	105.4	+	2981.88	=	3087.3

II. Custer NF
   A. Average annual water yield over a 75-year planning horizon was reported.
   B. Base water yield is 1070MAcFt (minimum level benchmark yield).
   C. Estimate decadal average annual increase in water yield over base by using allowable sale and planning period average annual yield.
   D. For example, increase in water yield for alternative 2 is estimated as follows:
      1. Planning period acreage annual yield = 1100 MAcFt or 30 MAcFt above base.
      2. The total 50-year increase over basic is 1500 MAcFt (50 yrs. x 30 MAcFt/yr).

3. Convert allowable sale to equivalents.

Period	Allowable sale (total period)	Allowable sale equivalents (total period)
1	6	26.25
2	13	99.45
3	19	210.64
4	22	332.91
5	25	443.13
	50-yr. totals =	1112.38

4. Calculate water yield per equivalent, 1500 MAcFt / 1112.38 = 1.34846 MAcFt/equivalent.
5. Calculate average annual increased yield by period.

Allowable sale equivalents x Yield/Equivalent = Increase

Period	(Aver. annual)				(Aver. annual)
1	2.6	x	1.35	=	3.5
2	9.9	x	1.35	=	13.4
3	21.1	x	1.35	=	28.5
4	33.3	x	1.35	=	45.0
5	44.3	x	1.35	=	59.8

E. Calculate the estimate for total water yield.

Period	Increased yield	+	Base	=	Total yield
1	3.5	+	1070	=	1073.5
2	13.4	+	1070	=	1083.4
3	28.5	+	1070	=	1098.5
4	45.0	+	1070	=	1115.0
5	59.8	+	1070	=	1129.8

III. Numerous Forests

A. Water yield was often reported as an increase over a base or natural yield. The increase was simply added to the base yield to get total yield.

1. If a base or natural yield was not reported, it was estimated by comparison with a neighboring or similar forest whose base yield was reported.
2. Proration by total forest acreage was used to estimate the base yields.

B. The total water yield meeting quality goals reported by many forests was often equal to total water yield. This was either indicated in the EIS or by the forests.

IV. Helena NF

A. Water yield was not reported and not available.

B. The forest provided the natural yield, 415,000 AcFt/yr.

C. The forest indicated 1 MMBF of timber harvest produces an additional 21 acre feet of water per year.

D. The forest indicated that water yield will recover to pre-harvest levels by the end of the 2nd decade after harvest.

1. Therefore, the carryover percentages for approximating water yield increases from timber harvest will be 75% and 33% for the 1st and 2nd decades, respectively (instead of the 75%, 66%, 50%, and 30% split used for other forests).

E. Use allowable sale data (in BF), base yield (415 MAcFt/yr.), harvest yield (21 AcFt/yr.), and carryover (75% and 33% to succeeding decades) to estimate scheduled water yield.

F. For example, the estimate of total water yield for alternative A is calculated as follows.

1. The coefficients for calculating total allowable sale equivalents are derived in the same manner as these for the four decade carryover coefficients described earlier.
2. These coefficients are:

Period	Allowable sale equivalents per year
1	3.375
2	5.61
3	1.815

3. The allowable sale equivalents (MMBF) for alternative A are:

Period	Allowable sale	Allowable sale equivalents
1	16.7	56.4
2	20.9	164.2
3	21.2	219.1
4	21.2	228.4
5	21.2	229.0

4. Then total additional yield is calculated as follows:

Period	Yield/MMBF (AcFt)	x	Allowable sale equivalents	=	Add. yield (AcFt)
1	21	x	56.4	=	1184.4
2	21	x	164.2	=	3448.2
3	21	x	219.1	=	4601.1
4	21	x	228.4	=	4796.4
5	21	x	229.0	=	4809.0

5. Total yield is calculated by simply adding the additional yield to base yield.

Period	Additional yield	+	Base yield	=	Total yield
1	1.18	+	415	=	416.18
2	3.45	+	415	=	418.45
3	4.60	+	415	=	419.6
4	4.80	+	415	=	419.8
5	4.81	+	415	=	419.81

Examples of Distinct Methodologies for Deriving and Estimating Sediment Yield

I. Beaverhead NF

A. Sediment was reported in periods 1, 3, and 5 only for the primary alternatives.

B. Sediment does not appear to have any positive linear relationship with road construction.

C. However, it does appear that sediment increases at a proportional rate. Period 3 is close to the median between periods 1 and 5 over all alternatives.

1. Interpolate to estimate periods 2 and 4.

II. Idaho Panhandle

A. Sediment yield was not reported and not available.

B. Use a neighboring forest, the Clearwater, to estimate sediment yield.

C. Estimate base sediment yield using total forest acreage.

1. Area of Clearwater = 1,837,116 acres.
2. Area of Idaho Panhandle = 2,500,000 acres.
3. Base sediment yield on Clearwater = 57.4 MTons/yr.
4. Estimated base yield for Idaho Panhandle is

$$\frac{2{,}500{,}000}{1{,}837{,}116} \times 57.4 = 78.1 \text{ MTons/year.}$$

D. Use increase in sediment yield and road construction data from the Clearwater to calculate a regression equation.

1. Then use road construction from Idaho Panhandle as independent variable in this regression to estimate increase in sediment yield on Idaho Panhandle.
2. The Clearwater regression has a low correlation coefficient, r = .28.
3. Try fitting regressions by decade across all Clearwater alternatives. These r values range from .76 to .97 (5 equations).
4. Use decadal regressions with analogous road construction data from Idaho Panhandle to estimate increases in sediment yield.
5. Then add these increases to the estimated base yield (78.1 MTons/year) to get total yields.

E. For example, the regression equations for alternative 1 are:

Period		
1	Y = .9842 X -9.9234	r = .97
2	Y = 1.008 X -3.7335	r = .76
3	Y = 1.2799 X -4.409	r = .97
4	Y = 1.1647 X +4.3735	r = .96
5	Y = 1.142 X +23.602	r = .80

1. Then, solve for increased sediment yield (Y) given road construction miles (X) and add to base yield (78.1 MTons/yr) to get total sediment yield.

Period	Road construction (x)	Increased yield	+ Base	= Total
1	310	295.2	78.1	373.3
2	227	225.1	78.1	303.2
3	163	204.2	78.1	282.3
4	98	118.5	78.1	196.6
5	79	113.8	78.1	191.9

III. Kootenai NF

A. Sediment was not reported. The forest could only provide yield for the no action alternative.

B. Calculate a regression using the no action sediment yield and timber output in BF.

1. The correlation with road construction and timber output in CF was not as good.
2. The regression equation is Y=4545X+43.54, r=.52.

C. Use this regression equation with timber output in BF from all other alternatives as independent variable to estimate sediment yields.

IV. Deerlodge NF

A. Sediment yield was not reported and not available.

B. Calculate a regression equation using the scheduled sediment yield and road construction from the Helena NF.

1. Y = .1652 X + 1.3373, r = .77.

C. Use this regression with road construction from the Deerlodge as the independent variable to estimate sediment yield.

V. Custer NF

A. Sediment yield was not reported and not available.

B. The forest provided a base yield of 2,647 MTONS/yr.

C. No strong linear relationship between road construction and sediment yield on neighboring forests existed.

D. The forest recommended using the ratio between base sediment yield and base water yield to estimate sediment yield.

1. Calculate the base sediment/water yield ratios.

$$\frac{2647 \text{ MTons}}{1070 \text{ MAcFt}} = 2.47 \text{ Tons/AcFt.}$$

2. Then multiply the scheduled water yield by this ratio to estimate the schedule for sediment yield.
3. For example, the sediment yield for alternative 1 is estimated as follows:

Period	Water yield	x	Ratio	=	Sediment yield
1	1072.8		2.47		2649.8
2	1077.3		2.47		2660.9
3	1081.1		2.47		2670.3
4	1083.8		2.47		2677.0
5	1085.0		2.47		2680.0

VI. Pike and San Isabel NF

A. Sediment yield was not reported and not available.

B. Use 50-year average road construction and 50-year average increase in sediment over base from each alternative on the Arapaho and Roosevelt NF in a regression equation to estimate the sediment yield on the Pike and San Isabel.

1. Road construction data from the Roosevelt was only available on 50-year average basis.
2. The regression equations is: Y = .1943 X +64.9 and r = .89.

C. Estimate base level sediment yield on Pike.

1. Area of Arapaho and Roosevelt = 1,471,963 acres.
2. Area of Pike = 2,751,736 acres.
3. The base level yield on the Roosevelt = 647.84 M Tons/yr.
4. The estimated base level yield on the Pike is: $\frac{2,751,736}{1,471,963}$ x 647.84 = 1211.09 MTons/yr.

D. Add the increase in yield estimated using the regression to the estimated base yield to get total sediment yield.

1. Use average annual road construction by decade from the Pike as the independent variable, X, for estimating increase in sediment yield.

VII. Arapaho and Roosevelt NF

A. The 50-year average increase in sediment yield over baseline was reported for all alternatives.

B. The increase in sediment yield over baseline for period 1 across all alternatives was reported.

C. The baseline yield was not reported. The forest provided this data, 647.84 MTons/yr.

D. Road construction was only available as a 50-year average.

E. Use 50-year average timber harvest in a regression with 50-year average increase in sediment yield to estimate schedule for sediment yield.

1. The Regression equation is Y = 6.1 X + 62.37 with r = .93.
2. Apply scheduled timber harvest to regression equation, as independent variable X, to estimate schedule of sediment yield increases.
3. Then add increases to base yield to get total yield.

VIII. Bighorn NF

A. Soil loss was reported.

B. Not all soil loss becomes sediment.

C. The forest indicated a 19% sediment delivery ratio would approximate sediment yield.

1. Apply sediment delivery ratio to schedule of soil loss to estimate schedule of sediment yield.

IX. Grand Mesa, Uncompahgre, and Gunnison NF

A. Sediment yield was reported in acre feet over current yield for 1st and 5th periods.

B. The forest indicated 1 AcFt sediment = 1600 Ton.

C. Current sediment yield was not reported.

D. Use White River NF to estimate current yield.

1. Prorate using forest acreage.

E. Convert reported yields to tons.

F. Use a regression with 1st and 5th period sediment yield and timber harvest (there was not a good linear relationship with road construction) to estimate yields for periods 2, 3, and 4.

1. Apply timber harvest in these periods as the independent variable in the regression equation.

X. Numerous Forests

A. Many forests reported soil loss instead of sediment yield, especially in Regions 3 and 4.

1. Most forests provided an estimate for a sediment delivery ratio.
2. If forests couldn't provide this estimate, the delivery ratio from a neighboring or similar forest was used.

XI. Coronado NF

A. Sediment yield was not reported and not available.

B. The DEIS indicates sediment yield will decrease because of watershed improvements.

C. Unsatisfactory watershed acres was scheduled.

D. Use a regression with Cibola NF unsatisfactory watershed acres and soil loss over natural to estimate Coronado soil loss over natural.

1. Use alternatives PA, B, C, D, and F from the Cibola since these alternatives display a range of watershed acres closest to those on the Coronado.
2. The regression is Y = .271421 X + 2621.73 with r=.81.
3. Apply the schedule of unsatisfactory watershed acres from the Coronado to this regression equation (independent variable X) to estimate soil loss over natural.

E. Estimate natural level soil loss on the Coronado by comparing with Cibola forest acreage and soil loss.

1. The area of the Cibola = 1,889,496 acres.
2. The area of the Coronado = 1,726,514 acres.
3. The Cibola natural level soil loss = 2102.5 MTons/yr.
4. The Coronado soil loss is $\frac{1,726,514}{1,889,496}$ x 2102.5 = 1921.14 MTons/yr.

F. Add estimated natural level of soil loss to estimated schedule of soil loss over natural to get schedule of total loss.

G. The forest provided an estimate of 10% for the sediment delivery ratio.

1. Apply this ratio to the schedule of total soil loss to estimate sediment yield.

XII. Coconino NF

A. Sediment yield was not reported and not available.

B. The EIS indicated that sediment should decrease due to watershed improvement projects and road obliteration.

C. Use watershed improvement data to estimate sediment yield.

D. The forest provided a current level of soil loss by vegetation type and total forest and approximated a 5-decade schedule for soil loss based on eventual treatment of all treatable unsatisfactory watershed acres.
   1. The current level of soil loss is 2572.36 MTons/yr.
   2. **Period** **Soil loss (MTons/yr)**

Period	Soil loss (MTons/yr)
1	2492.80
2	2331.20
3	2167.18
4	2038.34
5	2026.00

E. The EIS assigned a level of soil and watershed improvement activities to each alternative.
   1. Level #3 represents low level of watershed treatment, the current level.
   2. Level #4 represents 9-fold increase in watershed improvement over current.
   3. Level #5 represents high level of watershed improvement, about 32% over #4.
   4. Level #6 represents maximum funding for watershed improvement, about 50% over level #5 for periods 1 and 2 and 33% over level #5 for periods 3, 4, and 5.

F. The alternatives were assigned the following levels in the EIS:

1. PA	A	B	C	D	E	F	Max. PNV
3	3	4 (18% nonforested) 3 (82% forested)	3	5	3	3	3

G. Assume that the schedule of soil loss based on treating all unsatisfactory watersheds, that is D.2., equates to level #6.

H. Also assume linear and directly proportional relationships between funding and soil loss reductions from improvements.

I. Then, the level #6 schedule for additional soil loss reductions below the previous periods total soil loss in M Tons is as follows.

Period	Previous period loss	-	Present period loss	=	Level #6 soil loss reduction per period
1	2572.36	-	2492.80	=	79.56
2	2492.80	-	2331.20	=	161.60
3	2331.20	-	2167.18	=	164.02
4	2167.18	-	2038.34	=	128.84
5	2038.34	-	2026.00	=	11.74

J. Based on level #6 being 50% over level #5 funding for periods 1 and 2 and 33% over level #5 for periods 3, 4, and 5, the level #5 reduction in soil loss schedule is as follows.

Period	Soil loss reduction	
1	53.04	(1.50 x = 79.56, so x = 53.04)
2	107.73	etc.
3	123.32	(1.33 x = 164.02, so x = 123.32)
4	96.87	etc.
5	8.83	etc.

K. Based on level #5 being about 32% over level #4, level #4 reduction in soil loss schedule is as follows.

Period	Soil loss reduction	
1	40.18	(1.32 x = 53.04 so x = 40.18)
2	81.61	etc.
3	93.42	
4	72.83	
5	6.69	

L. Based on level #4 being about 9-fold increase over current or level #3, level #3 reduction in soil loss schedule is as follows.

Period	Soil loss reduction	
1	4.46	(9x=40.18 and x = 4.46)
2	9.07	etc.
3	10.38	
4	8.09	
5	.74	

M. Apply the above soil loss reduction schedules to each alternative as indicated in F. to estimate total soil loss schedules (start with period 1 loss reduction from current).
   1. For example, alternative PA was assigned level #3 and the estimation of its soil loss is as follows.

Period	Previous period total soil loss	-	Soil loss reduction	=	Total soil loss
1	2572.36	-	4.46	=	2567.90
2	2567.9	-	9.07	=	2558.83
3	2558.83	-	10.38	=	2548.45
4	2548.45	-	8.09	=	2540.36
5	2540.36	-	.74	=	2539.62

N. Then multiply soil loss schedules by 10%, the sediment delivery ratio stated in the EIS, to estimate sediment yield.

XIII. Salmon NF

A. Sediment yield was reported by decade and alternative as the highest percentage yield over natural for any one year in that decade.

B. The natural level was not reported.
   1. The forest provided a natural level of approximately 22 tons/sq. mi. and 2815.06 sq. mi. on the forest x 22 tons/sq. mi. = 61,931.38 Tons/yr.

C. The forest recommended a method to estimate scheduled sediment yield.
   1. Take 30% of highest percentage over natural reported to estimate the decadal annual average.
   2. Multiply the decadal average percentage over natural by the natural level and add back to natural.

3. Each sediment rate reported by stream type is assumed to be an increase to total forest sediment. For example, in period 1 of alternative 1 the sediment rate in resident only streams is 48%. The sediment rate in anadramous streams is 22%. Thus, .30 x .48 + .30 x .22 = .21 or 21%. Then .21 x 61.9 MTons/yr = 13.0 MTons/yr and 61.9 MTons + 13.0 MTons = 74.9 MTons/yr.

IX. Kisatchie NF

A. Sediment yield was not scheduled and not available.

B. 50-year total sediment yields from certain activities were reported by alternative.

C. The forest recommended a methodology for estimating scheduled sediment yield.

1. Use harvest activities, road construction, site preparation, prescribed fire, and skid trails data reported in the EIS in conjunction with sediment yield coefficients provided by the forest and total 50-year yield reported in the EIS to estimate scheduled sediment yield.

D. Period 1 of alternative A is used here as an example.

1. Estimate yield from harvest activities by multiplying acres accessed (pg IV-38) by a yield coefficient of .149 tons/acre. Thus, 18,150.6 acres/yr x .149 tons/acre = 2704.44 tons/yr.

2. Estimate yield from road construction by multiplying miles/year (pg. IV-38) by a conversion factor of 2.42 to get acres/yr and then multiply this product by a yield coefficient of 16.46 tons/acre to get tons sediment/yr. Thus, 94 mi/yr x 2.42 = 227.48 acres/yr and 227.48 acres/yr x 16.46 tons/acre = 3744.32 tons/yr.

3. The estimation of yield from site preparation proceeds as follows.

Assume site preparation is roughly equal to acres of reforestation (pg. IV-21).

Assume sediment yield (reported as total 50-year yield by alternative on pg. IV-27) is proportional to decadal average annual reforestation (pg. IV-21).

Since 50-year reforestation = 58.4 M Acres, and period 1, alternative A reforestation = 12.2 M Acres then 12.2 / 58.4 = .21 and .21 x 236,557 tons/50-yr = 49,417.7 tons/period 1 or 4.94 MTons/yr.

4. The estimation of yield from prescribed fire proceeds as follows.

Assume sediment/period from prescribed fire (reported as 50-yr total by alternative on pg. IV-29) is proportional to average annual acreage treated by prescribed fire (pg. IV-40).

50-year average annual acres treated = 316,810.

Average annual acres treated in period 5 = 64,870.

50-year sediment yield from prescribed fire acres = 282,481 tons.

Thus, estimated sediment yield in tons/period is

$\frac{64,870}{316,810}$ = 20.48% and .2048 x 282,481 tons

= 57,840.8 tons/period 1 or 5.78 M Tons/year.

5. Estimation of yield from skid trails is considered separately since skid trails were not considered in harvest activities.

50-year total sediment yield from skid trails was reported (pg. IV-25).

Assume yield from skid trails is proportional by period to timber harvest (pg. IV-19).

Since period 1 harvest = 28.5 MMCF,

50-year harvest = 194.1 MMCF, and

50-year sediment yield from skid trails = 3191 tons

then $\frac{28.5}{194.1}$ = 14.68%

and .1468 x 3191 = 468.54 tons/period or .05 MTons/yr.

6. Now aggregate above yields as follows.

harvest activities	=	2.7	MTons/yr
road construction	=	3.74	MTons/yr
site preparation	=	4.94	MTons/yr
prescribed fire	=	5.78	MTons/yr
skid trails	=	.05	MTons/yr
Total	=	17.21	MTons/yr

Examples of Distinct Methodologies for Deriving and Estimating Costs

I. Numerous Forests

A. Costs needed to be reported in common base year 1978 dollars.

B. To convert from 1980 and 1982 dollars, the following conversion factors were obtained from the table of implicit price deflators for gross national product, 1929-83.

1. 1980; $\frac{150.42}{178.42}$ = .8430669207

2. 1982; $\frac{150.42}{207.38}$ = .7253351336

II. Numerous Forests

A. Costs as reported often had to be aggregated or disaggregated to derive the total cost figure of interest in this study, i.e., operation and maintenance + capital investment costs + timber purchases road credits + forest fire fighting funds = total cost.

1. The following costs were subtracted out to the extent they were included in any reporting of forest costs; allocated and cooperator funds.

III. Manti-LaSal NF

A. Cost were reported for 3 periods.

1. The third period covered 3 decades.

2. Decadal averages were not available.

3. Use average for last three decades.

IV. Los Padres NF

A. Forest fire fighting costs (FFF) were not reported for benchmark alternatives.

B. Use average FFF costs from the primary alternatives to apply to the benchmarks.

V. Eldorado NF

A. Total cost reported for benchmark alternatives includes nonfederal costs.

1. The amount of nonfederal costs were not reported.

B. Nonfederal costs are .5 MM$ for all periods of all primary alternatives.

1. Assume the same for benchmark alternatives and subtract out of total costs.

VI. Several Forests

A. Some forests indicated that costs reported include negligible amounts of allocated funds which were not disaggregable.

B. Record costs as reported.

VII. Mononagahela NF

A. Costs were reported only for periods 1 and 5 while period 2, 3, and 4 costs were not available.

B. Costs are fully scheduled at 4% discount rate.

C. Use discounting formula to derive costs from schedule of discounted costs.

1. $V_o = \frac{V_n}{(1+p)}$ represents the formula for present net value (PNV)

where

V_o = value of sum of money when placed at interest, or after it has been discounted to its present value (PNV),

V_n = value of sum of money with interest, p, in n years hence,

n = # of years of interest bearing periods,

p = interest rate.

2. So, $V_n = V_o(1+p)^n = V_o(1.04)^n$.

VIII. Wayne NF

A. Costs were reported only for periods 1 and 5 but not available for periods 2, 3, and 4.

B. Interpolate to estimate periods 2, 3, and 4.

Baltic, Tony; Hof, John. 1988. Documentation of the National Forest System Resource Interactions Model. General Technical Report RM-155. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 30 p.

The National Forest System Resource Interactions Model is an upper level linear programming model developed to aid the analysis of multiresource interactions for the 1989 RPA National Assessment. This report documents the development and structure of this linear programming model, emphasizing its multilevel nature and the data requirements for such an approach. A brief description of the solution output that can be derived from the model is also presented. Finally, the resolution of data deficiencies, a major problem in applying such a multilevel optimization approach, is examined.

Keywords: Land management planning, multilevel planning, linear programming, forest economics, modeling

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky Mountains

Southwest

Great Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

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United States
Department of
Agriculture

Forest Service

**Rocky Mountain
Forest and Range
Experiment Station**

Fort Collins,
Colorado 80526

**General Technical
Report RM-156**

Forest and Rangeland Resource Interactions: A Supporting Technical Document for the 1989 RPA Assessment

John Hof and Tony Baltic

Preface

The Renewable Resources Planning Act of 1974 (RPA), P.L. 93–378, 88 Stat. 475, as amended, directed the Secretary of Agriculture to prepare a Renewable Resource Assessment by December 31, 1975, with an update in 1979 and each tenth year thereafter. The Assessment is to include "an analysis of present and anticipated uses, demand for, and supply of the renewable resources of forest, range, and other associated lands with consideration of the international resource situation, and an emphasis of pertinent supply, demand and price relationship trends" (Sec. 3.(a)).

The 1989 RPA Assessment is the third prepared in response to the RPA. It is composed of nine documents, including this one. The summary Assessment document presents an overview of analyses of the present situation and the outlook for the land base, outdoor recreation and wilderness, wildlife and fish, forest-range grazing, minerals, timber, and water. The complete analyses for each of these resources are contained in supporting technical documents. There is also a technical document presenting available information on interactions among the various resources.

The 1989 RPA Assessment continues a resource analysis heritage that the Forest Service has been carrying out in the United States for over a century. Congressional interest was first expressed in the Appropriations Act of August 15, 1876, which provided $2,000 for the employment of an expert to study and report upon forest conditions. Between 1880 and 1974, a number of assessments of the timber resource situation were prepared at irregular intervals. The 1974 RPA legislation established a periodic reporting requirement and broadened the resource coverage from timber alone to all renewable resources from forests and rangelands.

Hof, John; Baltic, Tony. 1987. Forest and rangeland resource interactions: A supporting technical document for the 1989 RPA assessment. General Technical Report RM–156. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 31 p.

This paper provides an analysis of the resource interactions implied by the forest planning alternatives for the National Forest System. It is concluded that current levels of production and environmental conditions can be maintained at current cost levels, and that even a modest scenario for future production increases will imply a substantial increase in cost.

Keywords: Resource interactions, optimization, linear programming, multilevel planning

General Technical Report RM-156 April 1988

Forest and Rangeland Resource Interactions: A Supporting Technical Document for the 1989 RPA Assessment

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Forest planners and economists throughout the National Forest System (in Regional Offices and in Forest Supervisor's Offices) were of enormous help in building the National Forest System Resource Interactions Model presented here. Also, in completing the literature review, the "Multiple Resource Interactions" chapter of the first review draft of "An Assessment of the Forest and Range Land Situation in the United States" (for 1980) was utilized extensively.

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Forest and Rangeland Resource Interactions: A Supporting Technical Document for the 1989 RPA Assessment

John Hof and Tony Baltic

INTRODUCTION

Information on resource interactions has been identified in the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) as amended by the National Forest Management Act of 1976 (NFMA) as an essential component of national renewable resource assessments. The term "resource interactions" simply refers to the mutual influence (in production) that different forest and rangeland resources have upon each other. Forest and rangeland resources are interactive in production because they share or are simultaneously affected by common land, labor, capital, and managerial inputs (Hof et al. 1985). The estimation of resource interactions has, however, proved to be very complex, especially where many resource outputs are involved over a large geographical area such as the National Forest System (or even just one National Forest System Region). Even after the completion of two national assessments, quantitative information on renewable resource interactions is still very limited. One major conclusion of the chapter "Multiple Resource Interactions" in the 1979 Assessment (USDA Forest Service 1981) states,

> At the present time, knowledge of these interactions is limited and should be the focus of increased attention from the forestry research community. The accuracy of any modeling efforts to quantify these resource interactions will be limited by the understanding of both the biology and economics of multiresource production.

The "Research Needs" chapter of the same assessment, states,

> Information on physical responses of forest and rangeland and the associated waters to management practices is still inadequate and especially so for multiresource interactions. The effort now going into describing and measuring the responses of these resources to management practices must be greatly expanded to provide the information necessary for efficient administration and management of forest and range lands.

This paper presents an analysis of resource interactions on the National Forest System lands that is based on the information developed in the forest planning effort mandated by the NFMA. The analysis addresses three questions regarding resource interactions:

1. What trends in costs are implied for simultaneously maintaining current production levels of all resources and environmental conditions on the National Forest System?

2. If the National Forest System were to maintain a constant share of total national resource production, would the demand (consumption) projections developed for individual resources in other recent assessment analyses be simultaneously achievable?

3. If an attempt were to be made for the National Forest System to maintain a constant proportion of these demand projections, what would the impacts be on cost trends and environmental conditions?

In both the text and the appendix, information is presented by National Forest System Region (numbered 1, 2, 3, 4, 5, 6, 8, and 9 for Northern, Rocky Mountain, Southwestern, Intermountain, California, Pacific Northwest, Southern, and Eastern regions, respectively). Maps of this regional configuration are available from many sources. No empirical results were included for Region 6 because planning alternatives were not available for this region; an addendum is planned when these alternatives become available.

A terse summary of the salient results is given in the sections entitled "Summary of Empirical Results" and "Conclusions." The analysis presented applies specifically to the National Forest System lands. In some cases, the results may be applicable to other lands, but as a general rule the reader is cautioned against such application.

STRUCTURE OF THE UPPER LEVEL MODELS

The National Forest System Resource Interactions Model (Baltic and Hof 1987) utilizes upper level linear programming (LP) models to develop technically efficient regional production possibilities. Discrete management alternatives generated by the local (forest) level planning LP models (Johnson et al. 1986a, 1986b, 1986c, 1986d; Kelly et al. 1986; Kent et al. 1985; Robinson et al. 1986) are used in the upper level models as the decision variables for quantifying resource interactions. Regional level results from this analysis may be integrated into a national level renewable resource planning process.

This approach was first demonstrated by Bartlett (1974) and Wong (1980). Later, Hof and Pickens (1986, 1987) developed the details of this approach and tested it in a case study. The approach performed very well at the higher level of analysis, given systematically defined lower level alternatives.

The test case involved utilizing a global model as a standard for comparison. Multilevel (two-level) models were then constructed using this global model. The global model used for the test was the NIMRUM model described in the appendix. Lower level models (local planning units) were developed simply by subdividing NIMRUM geographically. Timber and forage were the

only outputs modeled in this test case. Five upper level LP model configurations were constructed (1, 2A, 2B, 3, 4) that varied according to the number and range of management alternatives included. Nine tests for suboptimality were performed by solving the global model and each of the upper level models with three different global budget constraints and three price vectors for each global budget constraint. Comparisons of the solutions for the global and upper level models revealed a tendency of the upper level models to be only slightly suboptimal (table 1).

Table 2 shows an abbreviated version of the upper level model. In this example, only two forests (superscripted 1 and 2), two alternative management options (subscripted 1 and 2), and two forest outputs produced over two planning time periods (timber 1, timber 2, range 1, range 2) are included. The upper level models developed in this analysis cover five time periods and include as many as nine forest outputs, nineteen forests, and a total of 190 management alternatives.

In table 2, X_1^1 through X_2^2 are 0–1 decision variables representing selection (1) or rejection (0) of the discrete management alternatives developed by the national forests in their planning analyses. The column vectors of outputs associated with each management alternative are collected in the first six rows (accounting rows) of the model and are represented by the A_{ij} matrix of physical product/cost coefficients (for i = 1,....6, j = 1,....,4). For example X_1^1 represents the selection ($X_1^1 = 1$) or rejection ($X_1^1 = 0$) of the vector of outputs A_{i1} for i = 1,....,4 and cost A_{i1} for i = 5,6 associated with management alternative 1 in forest 1. The 0–1 constraint rows force the selection of only one alternative for each forest planning unit by constraining the aggregate value of a forest's deci-

Table 1.—Ratios of objective function solution values of different upper level linear programming models to those of the global model.

Global budget constraint	Relative timber prices	Upper level linear programming configurations				
		1	2A	2B	3	4
High	High	0.9908	0.9900	0.9869	0.9839	0.9723
High	Medium	.9942	.9942	.9942	.9276	.9942
High	Low	.9931	.9911	.9897	.9683	.9725
Medium	High	.9921	.9891	.9881	.9175	.9556
Medium	Medium	.9977	.9898	.9898	.8650	.9898
Medium	Low	.9963	.9918	.9925	.9498	.9633
Low	High	.9632	.9517	.9461	.9093	.8983
Low	Medium	.9922	.9826	.9826	.8850	.9826
Low	Low	.9960	.9928	.9936	.9063	.9415

Source: Hof and Pickens (1986).

Table 2.—An abbreviated upper level (regional) model structure.

		Decision variable				Accounting columns							
		Forest 1		Forest 2		Outputs				Cost 1	Cost 2	Type	Right-hand side (RHS)
		X_1^1	X_2^1	X_1^2	X_2^2	T1	T2	R1	R2	C1	C2		
Accounting rows	Timber 1	A_{11}	A_{12}	A_{13}	A_{14}	−1						=	0
	Timber 2	A_{21}	A_{22}	A_{23}	A_{24}		−1					=	0
	Range 1	A_{31}	A_{32}	A_{33}	A_{34}			−1				=	0
	Range 2	A_{41}	A_{42}	A_{43}	A_{44}				−1			=	0
	Cost 1	A_{51}	A_{52}	A_{53}	A_{54}					−1		=	0
	Cost 2	A_{61}	A_{62}	A_{63}	A_{64}						−1	=	0
	Objective Function									1	1		MIN
0–1 Decision variable constraints	Forest 1	1	1									=	1
	Forest 2			1	1							=	1
Production constraints (targets)	Timber 1					1						⩾	K_1
	Timber 2						1					⩾	K_2
	Range 1							1				⩾	K_3
	Range 2								1			⩾	K_4

sion variables to equal (Type column) a value of 1 (Right-hand side column). However, the decision variables in this model are continuous such that for any X, $0 \leqslant X \leqslant 1$. Therefore, the solution may include a partial selection of management alternatives, the combination of which satisfies the 0–1 constraints. For example, the management alternative options available in forest 1, X_1^1 and X_2^1, might solve with values of 0.6 and 0.4, respectively. Integer programming was not used explicitly to allow this interpolation. For further discussion of these partial selections, see Hof et al. (1985).

Each accounting row is associated with an accounting column. The accounting columns represent the problem solution variables for the forest product outputs and costs. These columns aggregate the outputs/costs of the alternatives selected to be in the solution. The aggregate outputs are then transferred to the production constraint rows and constrained to meet specified target values. For example, first period timber output (T1) is constrained to be greater than or equal to ($\geqslant$ type) K_1 (RHS). Aggregate costs are transferred to the objective function row and their sum is minimized.

The model in table 2 is structured to minimize the cost of regional forest production subject to constraints that force the selection of a "total" of one management alternative (and its corresponding vector of outputs and costs) per forest and that bound (constrain) the aggregate production of forest outputs.

Upper Level (Regional) Model Algebraic Formulation

The algebraic representation of the upper level model along with definitions for subscripts and variables follow:

$$\text{Minimize:} \quad \sum_{t=1}^{5} C_t^* \quad \text{(Objective function)}$$

$$\text{Subject to:} \quad \sum_{j=1}^{n} \sum_{i=1}^{m} P_{ijpt} X_{ij} - T_{pt} = 0 \;\forall\; p, t$$

(Production accounting rows—outputs)

$$\sum_{j=1}^{n} \sum_{i=1}^{m} C_{ijt} X_{ij} - C_t^* = 0 \;\forall\; t$$

(Production accounting rows—costs)

$$\sum_{i=1}^{m} X_{ij} = 1 \;\forall\; j$$

(0–1 Constraint rows)

$$T_{pt} \gtreqless K_{pt} \;\forall\; p, t$$

(Production constraint rows)

$$X_{ij} \geqslant 0 \;\forall\; i, j$$

$$T_{pt} \geqslant 0 \;\forall\; p, t$$

$$C_t^* \geqslant 0 \;\forall\; t$$

(Non-negativity constraints)

where

- i represents a management alternative from a lower level model
- j represents a lower level model (forest)
- t represents the time period
- p represents the product outputs from the lower level models considered in each upper level model
- m represents the number of management alternatives in a lower level model
- n represents the number of lower level models

and

- X_{ij} = management alternative i from lower level planning unit (forest) j
- P_{ijpt} = output of product p for time period t from management alternative i of forest j (A-matrix)
- C_{ijt} = cost of management alternative i from forest j and time period t
- T_{pt} = a variable to transfer the aggregate output of product p for time period t from the production accounting rows to the production constraint rows
- C_t^* = a variable to transfer the aggregate cost for time period t from the production accounting rows to the objective function
- K_{pt} = the production target for aggregate output of product p for time period t.

To address the questions posed in the introduction, a set of runs were performed with this model.

DESCRIPTION OF MODEL RUNS

For each region, a series of four solutions was obtained: Base Run, Run 1, Run 2, and Run 3.

The following output codes, followed by time period number (5 decades), are utilized in this paper:

Dispersed motorized recreation: (recreation visitor days (RVD's))	RECM
Dispersed nonmotorized recreation (RVD's):	RECNM
Total dispersed recreation (RVD's):	REC
Direct wildlife habitat improvement (acres)	HAB
Elk (number):	ELK
Deer (number):	DEER
Fish (pounds or number):	FISH
Range forage (animal unit months):	RNG
Timber (cubic feet):	TMBR
Water yield (acre-feet):	WTR
Sediment (tons):	SDMT
Cost (constant dollars):	COST

It was not possible to include some resources, such as minerals and air quality, because of the lack of sufficient data. The literature review in the appendix is similarly limited.

Base Run

The Base Run minimizes cost with lower bounds (constraints) on all outputs, except sediment which has up-

per bounds, over all periods at "NOW" levels. The NOW output levels are defined as the first period "No Action Alternative" output levels from the forest plans (summed over all forests). The No Action Alternative is the same as the "Current Management Direction Alternative." Base runs for all regions except Region 9 were feasible. Allowing range (RNG) to float (unbounded or unconstrained) in Region 9 resulted in a feasibility.

Run 1

In Run 1 the lower bounds for all outputs, except wildlife habitat improvement and sediment, were set at NOW levels times indexed demand projections (first period equals 100) for the outputs. *It is recognized that these are not true demand function projections in the economic sense, but they will be labeled as such for consistency with other RPA documents.* All indexed demand projections were derived from "An Assessment of the Forest and Rangeland Situation in the United States," USDA Forest Service (1981) or other research documents related to that publication; "An Analysis of the Timber Situation in the United States 1952–2030," USDA Forest Service (1982), and the "The South's Fourth Forest," USDA Forest Service (1987). *Applying these demand projections to the National Forest System implicitly assumes that the National Forest System will maintain its proportion of output production relative to the Nation's production as a whole.* The actual indexed demand projections are given in the results section, below. Habitat improvement and sediment were unconstrained in this run and the following runs because they are tracked as measures of the environmental impacts of meeting the given targets on the other outputs (while minimizing costs). For the results reported below, "rollover" runs were performed to insure that the indicated sediment and habitat improvement impacts are minimized, given the output levels and cost minimization of the given scenario. That is, sediment and habitat improvement were each minimized, subject to the given output levels and cost level. Because of the discrete nature of the data set, these rollovers had no effect.

Run 1 resulted in no feasible solution for all regions, necessitating Run 2. This implies that within the range of alternatives developed in the forest plans, it is not possible for the National Forest System to maintain a constant proportion of national production, if that national production is to simultaneously meet the demand projections developed for individual resources in other recent assessment analyses.

Run 2

Run 2 utilized a cardinal goal programming formulation to determine the minimum weighted and summed underachievement of projected demands from Run 1 that would allow feasibility for each region. Goal programming is a type of linear programming for achieving several objectives (or goals) simultaneously.

Table 3 depicts an abbreviated goal formulation of the problem in this analysis. To save space, only one time period and two outputs are considered, and the A-matrix is represented by the "t," "r," and "c" entries. This formulation differs substantially from the structure in table 2. The aggregate outputs collected in the accounting columns are transferred to the demand constraint rows. The right-hand sides of the demand constraint rows are set to be greater than or equal to projected demands (D_t and D_r) and deviational variables are added to the constraint rows to force any underachievement of demand into these columns, thus insuring that feasibility results. The deviational variables (underachievements) are then transferred to the objective function to be minimized. The objective function coefficients (W's) represent the relative weight assigned to each output underachievement.

Wildlife habitat improvement and sediment yield are not included in these new rows and columns because a projected demand for these outputs was not utilized in Run 1. In this case, the weights (or objective function coefficients) are based on the RPA values (USDA Forest Service 1981) assigned to each forest product output:

Output	**Value**
REC	$10/RVD
ELK	$100/Elk
DEER	$100/Deer
FISH	$.50/Fish
RNG	$8/AUM
TMBR	$40/MCF
WTR	$12/ACFT

Upper Level Cardinal Goal Formulation

The algebraic representation of this cardinal goal formulation along with definitions for subscripts and variables follow:

$$\text{Minimize:} \quad \sum_{t=1}^{5} \sum_{p=1}^{k} W_p Y_{pt}$$

(Objective function)

$$\text{Subject to:} \quad \sum_{j=1}^{n} \sum_{i=1}^{m} P_{ijpt} X_{ij} - T_{pt} = 0 \ \forall \ p, \ t$$

(Accounting rows—outputs)

$$\sum_{j=1}^{n} \sum_{i=1}^{m} C_{ijt} X_{ij} - C_t^{*} = 0 \ \forall \ t$$

(Accounting rows—costs)

$$\sum_{i=1}^{m} X_{ij} = 1 \ \forall \ j$$

(0–1 Constraint rows)

$$T_{pt} + Y_{pt} \geq D_{pt} \ \forall \ p, t$$

(Demand constraint rows) plus the Non-negativity constraints

where

i represents a management alternative from a lower level model
j represents a lower level model (a forest)
t represents the time period
p represents the product outputs from the lower level
k represents the number of outputs considered
m represents the number of management alternatives in a lower level model
n represents the number of lower level models

and

X_{ij} = management alternative i from lower level planning unit (forest) j
P_{ijpt} = output of product p for time period t from management alternative i of forest j (the A-matrix)
C_{ijt} = cost of management alternative i from forest j and time period t
T_{pt} = a variable to transfer the aggregate output of product p for time period t from the accounting rows to the demand constraint rows
C_t^* = a variable that collects the aggregate cost from the lower level planning units selected alternatives
D_{pt} = the projected demand constraint (NOW x indexed demand) for each product p in time period t
Y_{pt} = the positive deviational variable representing the underachievement of demand for product p in time period t
W_p = the weight or relative worth (RPA prices ÷ 10^4) assigned to each underachieved output Y_{pt} in the objective function.

Run 3

Run 1 showed that the original production targets (NOW x indexed demand projections) could not be satisfied for all outputs simultaneously. The goal formulation of Run 2 provided one set of production levels that are achievable in the model. Run 3 is the minimum cost "rollover" for the output levels obtained from Run 2; that is, the objective in Run 3 is to minimize cost subject to the production levels obtained from Run 2. There may be an overachievement of demand for some outputs in Run 2. In Run 3, these overachievements are disregarded—the bounds are set at projected demand (NOW x indexed demand) or production activity from Run 2, whichever is lower. As in the other runs, habitat improvement and sediment are left unconstrained.

EMPIRICAL RESULTS

This section displays the empirical results from the Base Run and Run 3 by region and discusses the multiresource implications of these joint production scenarios. These implications include cost and environmental impacts of output changes and the identification of limiting factors in terms of cost minimization. The analysis will demonstrate the usefulness and limitations of the upper level (regional) resource interactions models and provide insight as to areas where improvements might be made for future national level resource planning (optimization) analyses.

As described earlier, the Base Runs represent the baseline conditions when the production level of the current management situation (NOW) for the first planning period (each period representing one decade) is held constant as the target for future output projections (over the 50-year planning horizon). Run 3 for each region quantifies the potential resource allocations and interactions based on the attempted achievement of the projected regional demand over the same planning horizon. The results from the Base Run and Run 3 for each region are illustrated in one table. These two regional resource production scenarios are then compared graphically by region. The upper bar graph in each figure compares the

Table 3.—An abbreviated cardinal goal formulation.

		Decision variables				Accounting columns			Deviation variables			
		Forest 1		Forest 2		Outputs		Cost	Underachievement		Type	RHS
		X_1^1	X_2^1	X_1^2	X_2^2	Timber	Range	Cost	Timber	Range		
Accounting rows	Timber	t	t	t	t	-1					=	0
	Range	r	r	r	r		-1				=	0
	Cost	c	c	c	c			-1			=	0
Demand constraints	Timber					1			1		≥	D_t
	Range						1			1	≥	D_r
	Objective function								W	W		MIN
0-1 Decision variable constraints	Forest 1	1	1								=	1
	Forest 2			1	1						=	1

total (planning horizon) targeted production levels for those outputs with the baseline (NOW) levels. The lower graphs illustrate the environmental and cost impacts (in terms of projected levels of wildlife habitat improvement, sediment yield, and cost) that result from regional level cost minimization constrained by the targets shown in the upper graph and limited by the range of management alternatives (choice variables) generated in the forest planning effort.

The results presented in the tables are indexed. Thus, they are used to show relative comparisons, not to predict specific quantities of resource allocations. In all tables, the outputs are indexed such that the current (NOW) output levels, determined by totaling the outputs in the "No Action" forest alternatives in the first period, are equal to 100. In all tables, the unconstrained outputs and minimized costs are indexed similarly. Thus, in the Base Run, all targets for all time periods are equal to 100. And, in the Run 3, the targets are 100 in the first time period, and they then change according to the targets determined in Run 2.

Just as the actual quantities of resource outputs are not specified in this report, the discussion of limiting factors is also framed in relative terms. The existence of nonzero shadow prices identifies limiting factors, i.e., outputs whose demands or targets are stressing the resource production systems as modeled in this study. Thus, these are sensitive areas in the system where the potential for problems in resource interactions is greatest. For example, if certain products in specified time periods are shown to be limiting factors in the solution of the planning problem, relieving the constraint (target) on any one or combination of these outputs would reduce the total cost of this production scenario. It is important to emphasize, however, that an output might be indicated as a limiting factor either because of physical production properties or because of the way the forest planning alternatives are defined.

It is also important to emphasize the difference between the "Target" and "Demand" columns listed in the tables for Run 3 for each region. The "Demand" column represents the projected regional demand for each output by period as gleaned from several Forest Service documents previously identified. Based on the range of management alternatives (the choice variables and their related vectors of production outputs) available from the forest planning efforts, no upper level scenario could be developed for any region where all regional demand projections could be met simultaneously. Using goal programming techniques, a set of feasible output levels were determined by setting the objective of the goal problem to minimize weighted demand underachievement. These levels from the goal formulations are represented as the "Target" column in Run 3. Thus, these are also the production targets or constraints upon which determination of the limiting factors depend.

Ideally, a regional production scenario would just meet all targets at minimum cost. As discussed above, the discrete nature and limited range of choice variables available in the analysis results in the overachievement and underachievement of targets for certain outputs. Suppose that a certain product's projected output is in excess of its target. It would not be identified in the model formulations in this analysis as a limiting factor, because its target is not constraining. But, this overproduction may actually represent an additional cost to the system, especially where significant over- and underproduction exist in the same scenario.

Finally, the figures are intended to provide some insight as to the relative environmental and cost impacts that result from meeting output targets. In the figures, the indexes apply to total time horizon output levels. The indexes are again defined such that the total current (NOW) output level equals 100. There is no direct relationship between any environmental or investment indicator in a lower graph and any output target in an upper graph. For example, looking at a given figure, one might be tempted to assume that a large percentage of an increased cost (in the optimum production scenario over baseline) is attributable to a comparatively large increase targeted for, say, recreation. However, the indicated cost is a joint cost, simultaneously affected by all the outputs in a production scenario.

As previously stated, Region 6 is excluded because forest planning alternatives were not available for analysis.

Region 1

The results for Region 1 are shown in table 4 and in figure 1. Note that this is the only region where dispersed recreation could be disaggregated into the motorized and nonmotorized categories.

Base Run

The limiting factors in this scenario are wildlife habitat improvement, range, elk, and timber in period 1 and range in period 2. A number of outputs significantly exceed the current production levels (targets). By period 5, nonmotorized recreation and timber show the largest increases over current production levels (79% and 51%, respectively). While sediment increases over the planning horizon, as might be expected because of the relatively large increases in timber production, it never reaches the current (NOW) levels. This is an indication that environmental mitigation measures are incorporated in the forest planning alternatives. Cost requirements increase between the first and second periods but show a decline after that.

Run 3

All of the outputs except timber are limiting factors in this scenario. Of these limiting factors, only nonmotorized recreation and range in period 5 are targeted at their demand levels.

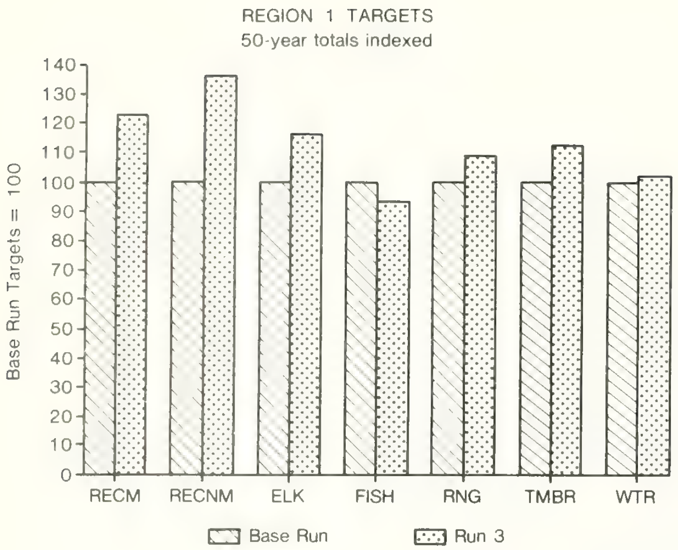
Demand for recreation and recreation-related outputs (elk and fish), show the largest increases over the plan-

Table 4.—Region 1 Base Run and Run 3 Results.

	Base Run			Run 3			
Output	Output level	Target	Limiting factor	Output level	Target	Demand	Limiting factor
RECM1	111	100		115	100	100	
RECM2	116	100		121	115	115	
RECM3	120	100		126	126	135	+
RECM4	124	100		133	133	155	+
RECM5	129	100		140	140	176	+
RECNM1	119	100		119	100	100	
RECNM2	141	100		132	115	115	
RECNM3	152	100		150	135	135	
RECNM4	163	100		161	155	155	
RECNM5	179	100		176	176	176	+
HAB1	100	100	+	100			
HAB2	102	100		78			
HAB3	102	100		79			
HAB4	103	100		79			
HAB5	103	100		80			
ELK1	100	100	+	100	100	100	+
ELK2	113	100		113	113	113	+
ELK3	116	100		122	122	125	+
ELK4	114	100		121	121	136	+
ELK5	112	100		125	125	141	+
FISH1	101	100		97	97	100	+
FISH2	103	100		95	95	117	+
FISH3	103	100		93	93	135	+
FISH4	103	100		91	91	155	+
FISH5	102	100		91	91	169	+
RNG1	100	100	+	97	97	100	+
RNG2	100	100	+	103	103	116	+
RNG3	100	100		109	109	120	+
RNG4	102	100		112	112	122	+
RNG5	106	100		125	125	125	+
TMBR1	100	100	+	152	100	100	
TMBR2	120	100		185	102	102	
TMBR3	119	100		181	116	116	
TMBR4	137	100		195	118	118	
TMBR5	151	100		243	117	117	
WTR1	100	100		100	100	100	
WTR2	101	100		101	101	104	+
WTR3	101	100		102	102	110	+
WTR4	102	100		103	103	115	+
WTR5	102	100		103	103	119	+
SDMT1	93	100		104			
SDMT2	96	100		99			
SDMT3	96	100		100			
SDMT4	99	100		102			
SDMT5	98	100		99			
COST1	93			147			
COST2	95			125			
COST3	91			121			
COST4	91			121			
COST5	92			130			

ning horizon (between 41% and 76%). Grazing demand increases by 25% while timber and water demands show the smallest increases (17% and 19%, respectively). However, in Run 2, projected demand is met in all periods only for dispersed nonmotorized recreation and timber. Water demand is met only in the first period and fish production not only fails to meet demands in all periods but is underachieved by as much as 46% (fish production decreased over the planning horizon as demand increased). Water and fish are clearly critical factors in this region. Timber is the only output that exceeds its targeted (equivalent to projected demand in this case) production levels in all periods. In fact, timber output exceeds its target levels by as much as 108% (in period 5). Nonmotorized recreation exceeds its target in all but the last period (by as much as 19%).

Wildlife habitat improvements, an output used in this analysis as an indicator of environmental impact, shows a sizable decrease from the current (NOW) situation over most of the planning horizon (approximately 21% less). Projections of fish production over the entire planning horizon also fail to stay above current levels. Sediment, the other indicator of environmental impact, fluctuates but is slightly below current levels by the end of the plan-



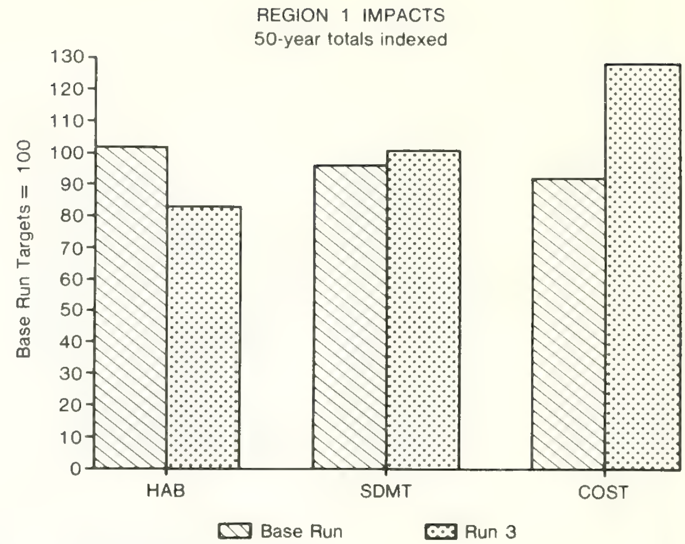


Figure 1.—Fifty-year summary of results: Region 1.

ning horizon. Although costs are substantially above current levels in all periods, they do decline until increasing in the last period.

In view of the very high levels of projected timber outputs in relation to current production, the projected sediment yields suggest a considerable effort in the mitigation of environmental impacts. Overall, costs are at a significantly higher level than current costs.

Graphic Summary of Results

In figure 1, the Run 3 scenario has recreation targeted for the largest production increase in this region, followed by elk and then timber and range. Water is targeted for a very slight increase while the Run 3 target for fish is the only one below the Base level. The environmental and cost impacts that result from the Run 3 scenario that achieves these targets are shown in the right-hand graph of figure 1. As would be expected, costs go up—by approximately 40%. Sediment yield increases slightly while wildlife habitat improvement shows a marked decrease.

Region 2

The results for Region 2 are shown in table 5 and in figure 2. Note that data on fish production were not available for this region.

Base Run

The limiting factors in this scenario are wildlife habitat improvement, range, timber, and sediment yield in period 1 and wildlife habitat improvement in period 4. Thus, the first period and wildlife habitat improvement are of particular interest in this region.

Recreation and elk are projected to have the largest increases over current production (59% and 36%, respectively, by the end of the planning horizon). Timber increases up to 21% by period 5 while range also shows a trend of increases but only up to 7% over current levels. Wildlife habitat improvements increase, then drop back down to current levels in period 4, then jump to their highest level in the last planning period. Water and sediment yields remain almost constant at current levels throughout the planning horizon. Costs start out below current levels and move up to just over the current level by the end of the planning horizon.

Run 3

Recreation and elk are limiting factors in period 5, and range and water are limiting factors after period 1 in this scenario. However, all limiting factors involve targets that are less than projected demand.

Timber is the only output for which projected demands are achieved in all periods in Run 2., Furthermore, it is indicated to be produced in excess of demand by substantial amounts (26% by period 5). Recreation, elk, and range in general come fairly close to meeting projected demands in Run 2, demonstrating moderate underachievements or overachievements in various periods throughout the planning horizon. All outputs whose targets are less than the demand projections, with the exception of water, still show a steady increase in projected output over the planning horizon. The target for water yield stays essentially constant at the current levels, while demand increases steadily up to 18% by the last period. Water appears to be critical in this scenario.

Sediment yield also remains constant at approximately current levels. Constant sediment yield just below current levels indicates concerted efforts at mitigation. Wildlife habitat improvements fluctuate, for the most part remaining above current levels but dropping below current levels in period 4. Costs show a steady increase to 39% above current levels by the last period. Increasing costs would be expected given steadily increasing production of most outputs.

Table 5.—Region 2 Base Run and Run 3 Results.

Output	Base Run Output level	Base Run Target	Base Run Limiting factor	Run 3 Output level	Run 3 Target	Run 3 Demand	Run 3 Limiting factor
REC1	102	100		106	100	100	
REC2	117	100		124	115	115	
REC3	132	100		139	135	135	
REC4	146	100		156	155	155	
REC5	159	100		172	172	176	+
HAB1	100	100	+	107			
HAB2	106	100		107			
HAB3	112	100		110			
HAB4	100	100	+	92			
HAB5	113	100		108			
ELK1	117	100		117	100	100	
ELK2	118	100		118	113	113	
ELK3	131	100		128	125	125	
ELK4	134	100		132	132	136	
ELK5	136	100		134	134	141	+
RNG1	100	100	+	104	100	100	
RNG2	103	100		110	110	111	+
RNG3	105	100		113	113	116	+
RNG4	106	100		116	116	118	+
RNG5	107	100		117	117	120	+
TMBR1	100	100	+	116	100	100	
TMBR2	104	100		130	114	114	
TMBR3	111	100		137	119	119	
TMBR4	115	100		146	123	123	
TMBR5	121	100		153	121	121	
WTR1	100	100		100	100	100	
WTR2	100	100		101	101	103	+
WTR3	101	100		101	101	109	+
WTR4	101	100		101	101	114	+
WTR5	101	100		101	101	118	+
SDMT1	100	100	+	100			
SDMT2	99	100		99			
SDMT3	100	100		99			
SDMT4	99	100		99			
SDMT5	99	100		99			
COST1	94			111			
COST2	91			120			
COST3	94			129			
COST4	97			127			
COST5	103			139			

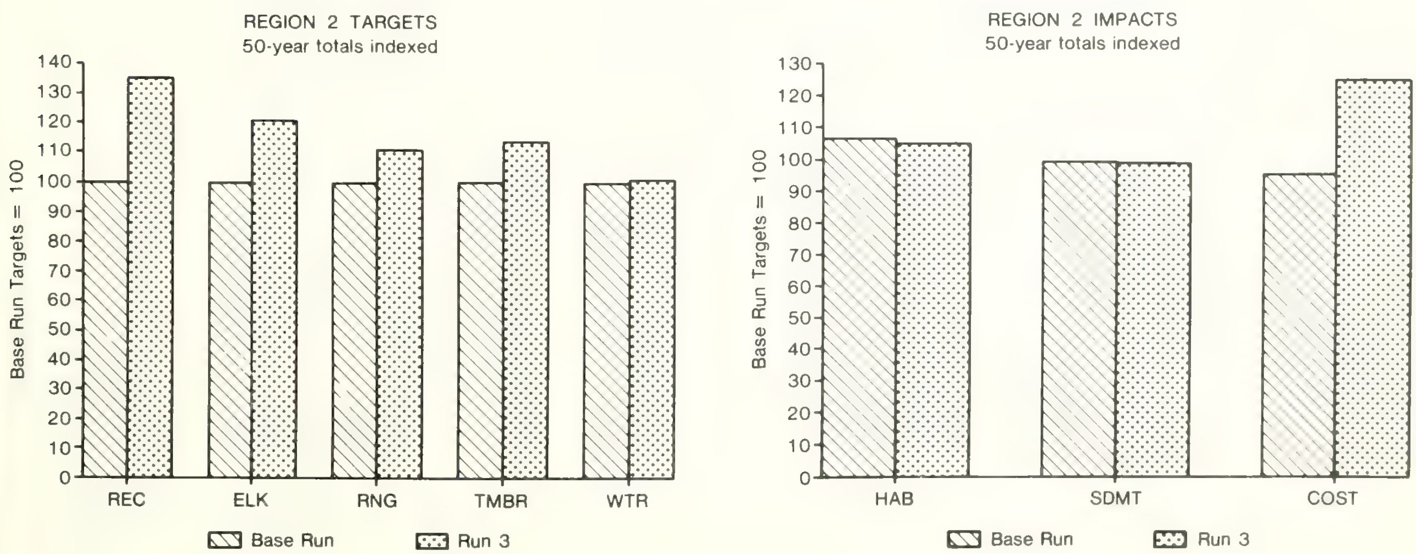


Figure 2.—Fifty-year summary of results: Region 2.

Graphic Summary of Results

Figure 2 depicts the Run 3 scenario as one with recreation output targeted for the largest increase followed by elk, timber, and then range. The water target stays just about constant at Base levels. Environmental impacts resulting from this scenario appear to be minimal. Cost requirements increase by approximately 30% over current levels.

Region 3

The results for Region 3 are shown in table 6 and in figure 3. Note that data on fish production were not available for this region.

Base Run

Limiting factors in this scenario include recreation, elk, and timber in period 1 and range in period 2. Recreation and wildlife habitat improvement show the largest increases in production (59% and 60% over current levels, respectively). Timber increases at a more moderate rate (up to 7%). Elk, range, and water yield remain relatively constant at not much higher levels than current. Sediment yield, however, is indicated to decrease dramatically (as much as 32% less than current levels by period 5). Cost increases slightly through the planning horizon, but remains below current levels in all periods.

A review of the forest plans in this region reveals that current soil and range conditions are often in the very poor category because of a combination of historical overgrazing and unique geologic and weather conditions. Thus, the forest planning alternatives all call for extensive watershed improvement measures as reflected by the figures for sediment yield in this baseline run.

Run 3

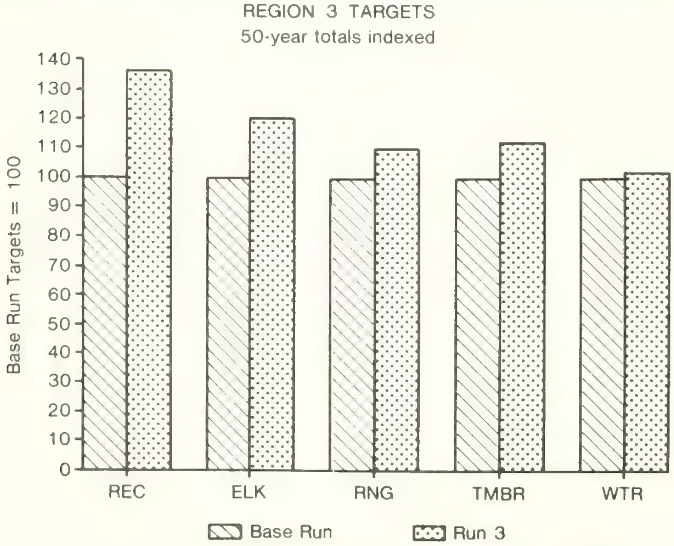
The limiting factors in this management scenario are elk in the middle periods, range after period 1, water in the last two periods, and recreation in period 5. Recreation is the only factor limiting at its projected demand, though the limiting water target from Run 2 is just under its projected demand. Recreation and timber are the only outputs with projected demands that are met in Run 2 in all periods.

Timber is indicated to be substantially in excess of its targets in all periods (between 24% and 35% greater). As in Region 2, water is a critical resource in this region. Unlike Region 2, the water yield targets are close to the demand projections. Range also appears to be a critical resource in this region. Reductions in sediment yield relative to current levels reflect substantial efforts in watershed improvement projects and other mitigative measures (especially in view of the indicated large increases in timber production).

However, the most conspicuous (and also potentially misleading) result from this scenario involves wildlife habitat improvement. An increase in this output over current production of 271% by the last period is indicated. In reviewing the data records from individual forest planning documents, it is apparent that a wide range in this output between alternatives within three forests, the relatively small number of alternative choices, and the discrete nature of the model lead to this result. These large increases in habitat improvement seem consistent with the large projected increase in elk numbers (a wildlife indicator species). Costs rise substantially over current levels. This is not surprising in view of the substantial increases in several outputs and the efforts to reduce sedimentation and improve wildlife habitat.

Graphic Summary of Results

Recreation and a recreation-related output, elk, are targeted for the largest increases in production in the Run 3 scenario (fig. 3). Timber and range also reflect targeted increases (approximately 10%) above the Base level. Environmental impacts appear to be significant on



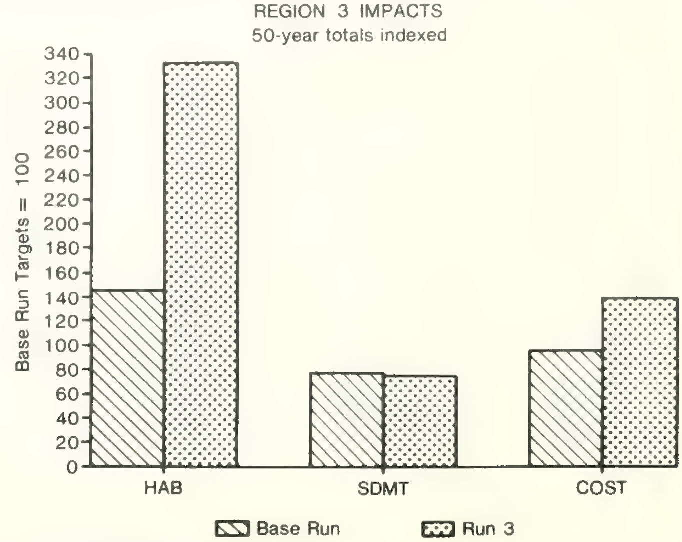


Figure 3.—Fifty-year summary of results: Region 3.

Table 6.—Region 3 Base Run and Run 3 Results.

Output	Base Run Output level	Base Run Target	Base Run Limiting factor	Run 3 Output level	Run 3 Target	Run 3 Demand	Run 3 Limiting factor
REC1	100	100	+	105	100	100	
REC2	120	100		123	115	115	
REC3	132	100		141	135	135	
REC4	145	100		157	155	155	
REC5	159	100		176	176	176	+
HAB1	131	100		285			
HAB2	141	100		329			
HAB3	145	100		336			
HAB4	150	100		348			
HAB5	160	100		371			
ELK1	100	100	+	105	100	100	
ELK2	101	100		111	111	113	+
ELK3	102	100		121	121	125	+
ELK4	101	100		131	131	136	+
ELK5	101	100		141	141	141	
RNG1	101	100		104	100	100	
RNG2	100	100	+	107	107	119	+
RNG3	101	100		112	112	122	+
RNG4	101	100		115	115	124	+
RNG5	101	100		117	117	126	+
TMBR1	100	100	+	125	100	100	
TMBR2	104	100		139	112	112	
TMBR3	107	100		154	116	116	
TMBR4	106	100		155	118	118	
TMBR5	107	100		158	117	117	
WTR1	100	100		102	100	100	
WTR2	101	100		103	97	97	
WTR3	101	100		105	102	102	
WTR4	101	100		106	106	107	+
WTR5	101	100		106	106	110	+
SDMT1	93	100		91			
SDMT2	81	100		79			
SDMT3	76	100		72			
SDMT4	72	100		68			
SDMT5	68	100		64			
COST1	96			132			
COST2	97			136			
COST3	97			138			
COST4	96			142			
COST5	97			146			

the positive side, especially in view of the tremendous increase in wildlife habitat improvement (although most of this is attributable to only three forests). The sediment levels in figure 3 both represent levels substantially below current levels. Cost increases appear to be in line with the other results summarized in this figure.

Region 4

The results from Region 4 are shown in table 7 and in figure 4. Note that fish data were not available for this region.

Base Run

The limiting factors in this scenario are recreation, wildlife habitat improvement, range, and timber in period 1, range and timber in period 4, and timber in period 5. Recreation shows the largest increase in output (57% by period 5). Wildlife habitat improvement also increases substantially while elk increases at a more moderate rate. All other outputs remain close to current production levels. Cost, however, shows a significant decrease from current levels (approximately 16% below current levels over all periods).

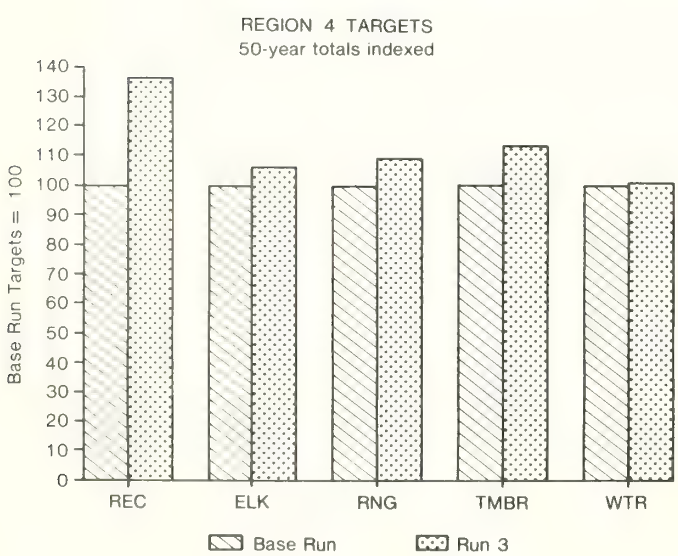
Run 3

The limiting factors in this scenario are elk, range, and water after period 1, and recreation in period 5. Recreation is the only factor limiting at its projected demand, while water yield is limiting at levels well below the projected demand (14% and 17%, respectively, in periods 4 and 5).

Projected demands increase substantially for all outputs (from 76% for recreation to 18% for timber by the last period). However, recreation and timber are the only outputs whose targets from Run 2 are equal to projected demand. Projected timber output exceeds its targets by

Table 7.—Region 4 Base Run and Run 3 Results.

Output	Base Run: Output level	Base Run: Target	Base Run: Limiting factor	Run 3: Output level	Run 3: Target	Run 3: Demand	Run 3: Limiting factor
REC1	100	100	+	102	100	100	
REC2	114	100		123	115	115	
REC3	127	100		140	135	135	
REC4	141	100		158	155	155	
REC5	157	100		176	176	176	+
HAB1	100	100	+	105			
HAB2	122	100		127			
HAB3	123	100		135			
HAB4	128	100		137			
HAB5	128	100		134			
ELK1	102	100		106	100	100	
ELK2	105	100		108	108	113	+
ELK3	107	100		109	109	125	+
ELK4	108	100		108	108	136	+
ELK5	109	100		107	107	141	+
RNG1	100	100	+	103	100	100	
RNG2	100	100		108	108	119	+
RNG3	100	100		111	111	122	+
RNG4	100	100	+	112	112	124	+
RNG5	101	100		114	114	126	+
TMBR1	100	100	+	148	100	100	
TMBR2	104	100		160	113	113	
TMBR3	102	100		160	117	117	
TMBR4	100	100	+	151	119	119	
TMBR5	100	100	+	150	118	118	
WTR1	100	100		100	100	100	
WTR2	100	100		101	101	105	+
WTR3	101	100		101	101	112	+
WTR4	101	100		101	101	117	+
WTR5	101	100		101	101	122	+
SDMT1	99	100		102			
SDMT2	99	100		101			
SDMT3	99	100		101			
SDMT4	99	100		101			
SDMT5	99	100		101			
COST1	86			124			
COST2	86			129			
COST3	83			127			
COST4	83			130			
COST5	84			127			



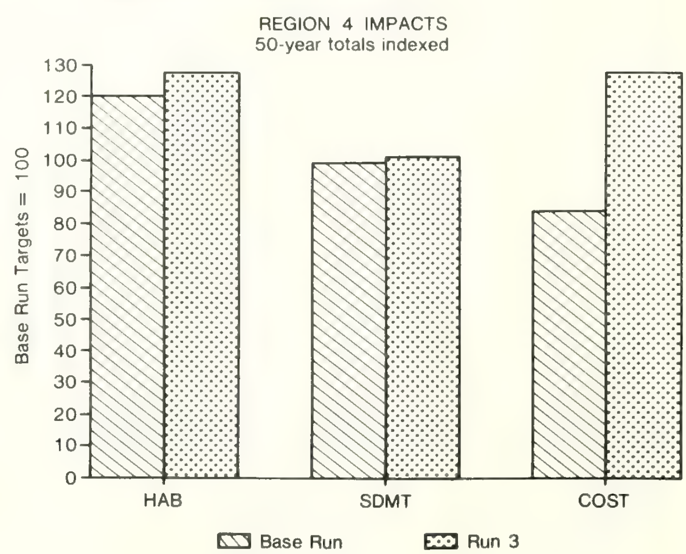


Figure 4.—Fifty-year summary of results: Region 4.

amounts from 27% to 48%. At the same time, elk, range, and water yield meet demand projections only in the first period. Water is clearly a critical factor in this region.

Sediment yield remains constant just above current levels indicating mitigation measures related to timber production are utilized in the forest planning alternatives. Wildlife habitat also shows steady improvements. Cost increases moderately throughout the planning horizon. This is consistent with the other results reported.

Graphic Summary of Results

Figure 4 indicates that recreation is the output targeted for the largest projected increases in the Run 3 scenario. All other outputs except water yield are also targeted for increased production above the Base levels. Environmental impacts from this scenario appear to be limited, while cost displays a substantial increase.

Region 5

The results from Region 5 are shown in table 8 and figure 5. Note that deer replaces elk as the wildlife indicator species in this region. Also, data on sediment yield were not available in this region.

Base Run

The limiting factors in this scenario include recreation and timber in period 1, and water yield in periods 4 and 5. Recreation shows the greatest increase in projected output (46% by the last period). Deer and range increase moderately; all other outputs remain relatively constant at or near current production levels, except wildlife habitat improvement, which decreases. Cost, however, displays a substantial increase (25% by the last period). This would imply that maintaining production at Base levels would involve increased costs.

Run 3

The limiting factors in the Run 3 scenario include recreation, deer, and timber in periods 4 and 5, and fish and water after the first period. Projected demands increase substantially across all resource outputs. The targets from Run 2 for recreation, deer, range, and timber meet or closely approximate their demand projections, while fish and water targets fall short of their projected demands.

Range output exceeds its target in all periods. The results with respect to water may have particularly significant implications. Water is a limiting factor at a target level well below demand. A similar situation exists for fish production.

As in Region 3, the most conspicuous (and potentially misleading) result involves wildlife habitat improvement, where almost a threefold increase occurs between the current (NOW) situation and the Run 3 solution. This occurs for the same reason as in Region 3, but only one forest is involved here. A very large response in this resource in certain alternatives and the discrete nature of the model makes this result occur. Finally, cost shows a substantial increase over current levels throughout the planning horizon. This is consistent with the previously discussed results.

Graphic Summary of Results

In figure 5, recreation and timber are shown to be targeted for the largest increases in production while water is the only output that is targeted to remain constant at Base levels in the Run 3 scenario. Environmental impact, represented by wildlife habitat improvement, would appear to be significantly positive. However, this

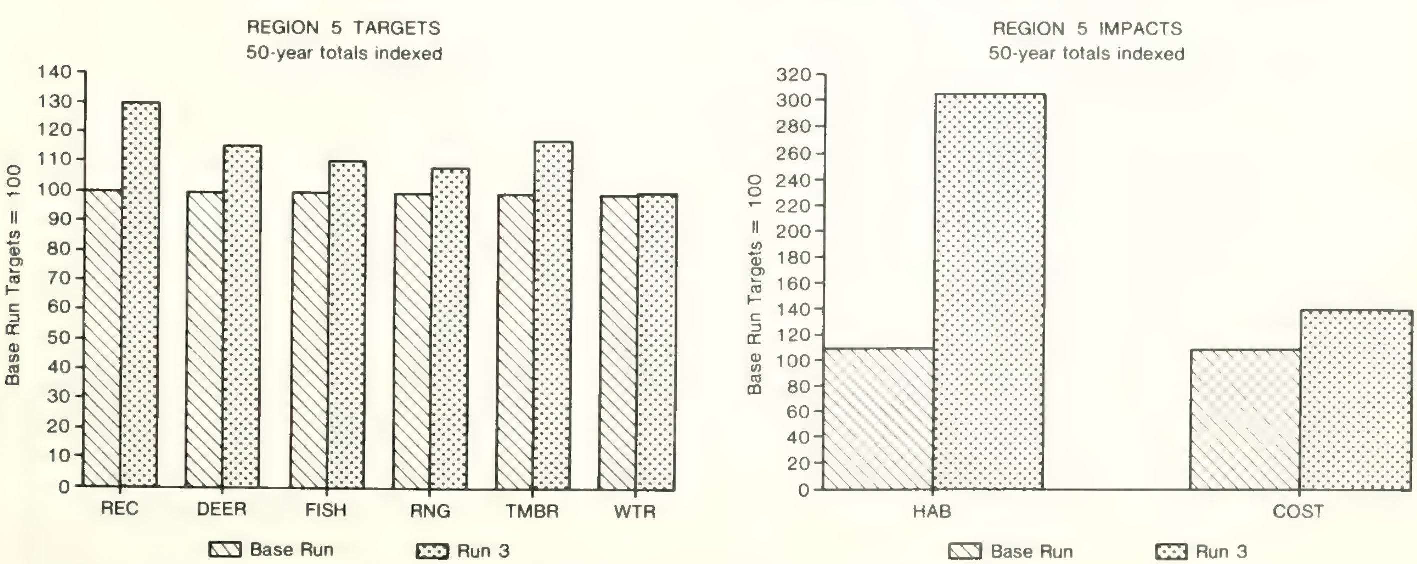


Figure 5.—Fifty-year summary of results: Region 5.

Table 8.—Region 5 Base Run and Run 3 Results.

	Base Run			Run 3			
Output	Output level	Target	Limiting factor	Output level	Target	Demand	Limiting factor
REC1	100	100	+	103	100	100	
REC2	113	100		118	114	114	
REC3	124	100		132	131	131	
REC4	135	100		146	146	149	+
REC5	146	100		159	159	168	+
HAB1	121	100		314			
HAB2	110	100		307			
HAB3	106	100		294			
HAB4	106	100		299			
HAB5	103	100		316			
DEER1	103	100		109	100	100	
DEER2	106	100		115	110	110	
DEER3	108	100		121	118	118	
DEER4	110	100		124	124	126	+
DEER5	112	100		128	128	128	+
FISH1	102	100		106	100	100	
FISH2	103	100		111	111	118	+
FISH3	103	100		114	114	132	+
FISH4	102	100		114	114	146	+
FISH5	102	100		116	116	157	+
RNG1	101	100		113	100	100	
RNG2	107	100		118	107	107	
RNG3	112	100		121	111	111	
RNG4	113	100		125	112	112	
RNG5	116	100		129	113	113	
TMBR1	100	100	+	118	100	100	
TMBR2	102	100		123	110	110	
TMBR3	102	100		126	123	123	
TMBR4	101	100		127	127	127	+
TMBR5	102	100		129	129	133	+
WTR1	100	100		101	100	100	
WTR2	100	100		101	101	107	+
WTR3	100	100		101	101	113	+
WTR4	100	100	+	101	101	116	+
WTR5	100	100	+	100	100	120	+
COST1	96			118			
COST2	100			121			
COST3	108			134			
COST4	116			152			
COST5	125			172			

may be a specious result as indicated above. Cost requirements appear to be significantly higher for the Run 3 scenario than for the Base scenario.

Region 8

The results from Region 8 are shown in table 9 and in figure 6. As in Region 5, deer is the wildlife indicator species in this region. Also, data on fish production were not available for this region.

Base Run

Recreation, deer, range, timber, and water yield in period 1, sediment in period 3, and deer and water yield in period 5 are the limiting factors in the Base scenario. Recreation and timber show large increases in projected outputs (37% and 49%, respectively) while all other outputs except water show much smaller increases, some even declining in later periods. Water yield remains constant at current levels throughout the planning horizon. Sediment yield starts out 11% below current (NOW) levels and rises to the current level by period 4. This would indicate that the forest planning alternatives include substantial efforts at mitigation of this impact in view of the large increases in timber production. Costs are less than current levels early in this scenario, but increase to 10% above current levels by period 5.

Run 3

The limiting factors in this scenario are recreation and range after period 2, and deer and water after period 1. Note that the limiting targets from Run 2 on water yield are well below projected demand. In fact, they are at current production. This suggests that it could be quite costly to meet projected demands for water in this region. While water yield in this scenario falls well short of projected demand, timber output substantially exceeds de-

Table 9.—Region 8 Base Run and Run 3 Results.

Output	Base Run			Run 3			
	Output level	Target	Limiting factor	Output level	Target	Demand	Limiting factor
REC1	100	100	+	104	100	100	
REC2	110	100		119	114	114	
REC3	119	100		134	134	134	+
REC4	129	100		150	150	154	+
REC5	137	100		176	176	176	+
HAB1	103	100		106			
HAB2	103	100		106			
HAB3	104	100		106			
HAB4	103	100		109			
HAB5	104	100		110			
DEER1	100	100	+	107	100	100	
DEER2	102	100		105	105	111	+
DEER3	103	100		111	111	119	+
DEER4	101	100		116	116	127	+
DEER5	100	100	+	113	113	132	+
RNG1	100	100	+	105	100	100	
RNG2	105	100		99	99	109	
RNG3	109	100		99	99	113	+
RNG4	103	100		105	105	116	+
RNG5	104	100		96	96	118	+
TMBR1	100	100	+	110	100	100	
TMBR2	113	100		133	111	111	
TMBR3	127	100		167	118	118	
TMBR4	140	100		187	125	125	
TMBR5	149	100		201	126	126	
WTR1	100	100	+	100	100	100	
WTR2	100	100		100	100	118	+
WTR3	100	100		100	100	134	+
WTR4	100	100		100	100	160	+
WTR5	100	100	+	100	100	166	+
SDMT1	89	100		95			
SDMT2	91	100		102			
SDMT3	100	100	+	107			
SDMT4	100	100		111			
SDMT5	97	100		101			
COST1	92			105			
COST2	97			127			
COST3	101			134			
COST4	108			135			
COST5	110			134			

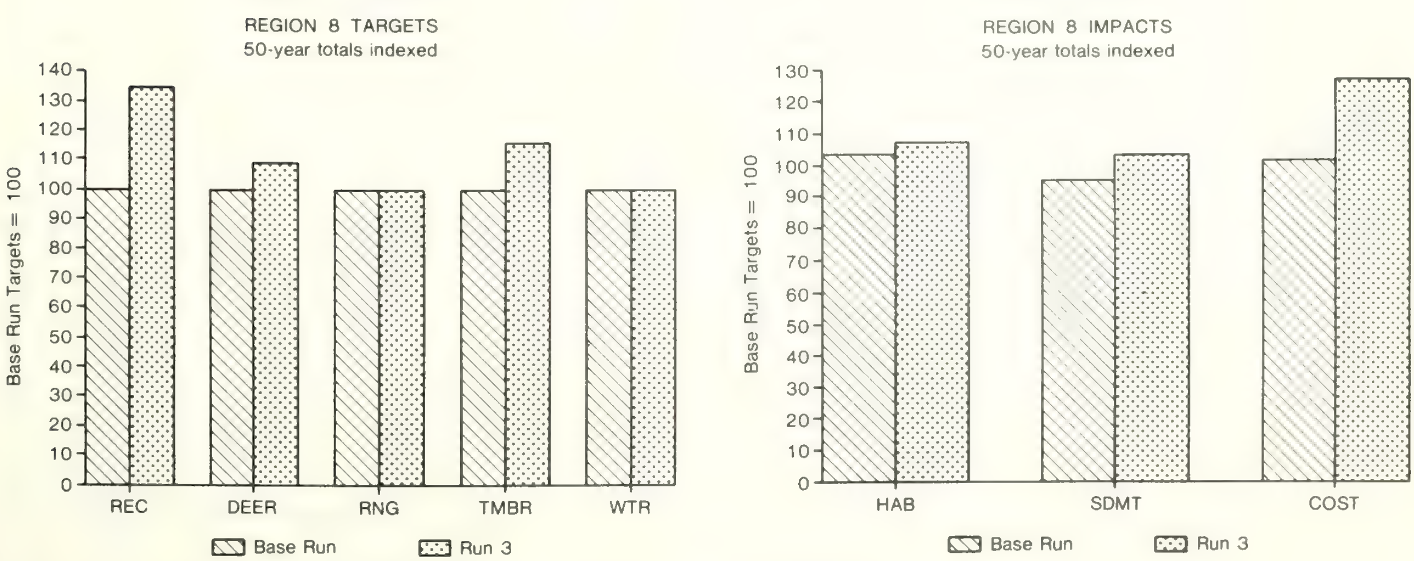


Figure 6.—Fifty-year summary of results: Region 8.

mand in all periods. Recreation shows the largest increase in projected demand and outputs are indicated to meet this demand. Except for the first period, targets from Run 2 for deer and range outputs fall short of their demands. Despite a steady increase in demand from current levels, output for range does not reach current levels in three periods.

Sediment shows mixed results. It increases by up to 11% over current levels by period 4, then falls back to approximately current yield in period 5. Wildlife habitat shows modest increases over current levels. Costs increase steadily to 34% higher than current levels by the last period. These results appear to be consistent with the targeted output increases in this scenario.

Graphic Summary of Results

As figure 6 shows, recreation is targeted for the largest increase in production, followed by timber then deer in the Run 3 scenario. Range and water are projected to remain near Base levels. Both environmental and cost impacts appear to be minimal in this scenario, although some increase in sediment and cost is indicated above the Base levels.

Region 9

The results from Region 9 are shown in table 10 and in figure 7. Note that data for deer, water, and sediment were not available for this region.

Base Run

The limiting factors in this scenario are recreation, wildlife habitat improvement, and timber in period 1. Timber and wildlife habitat improvement are indicated to experience substantial increases in output, while recreation increases are more moderate. Range, meanwhile, is limited to output levels well below current levels throughout the planning horizon. With the forest management alternatives available, it was not physically possible to maintain range output at current levels.

Run 3

The limiting factors in this scenario are timber in period 1, range in period 2, recreation in period 4, and recreation and range in period 5. The targets from Run 2 on range are limiting below its projected demand levels. However, timber output is generally above its demand projection (17% by the last period). Recreation outputs approximate demands while wildlife habitat improvements fall well below current levels in the first two periods. Considering the increase in projected outputs, especially timber, cost results are quite stable.

Graphic Summary of Results

As figure 7 shows, timber is targeted for the largest increase in the Run 3 scenario. Recreation is also targeted for an increase, while range targets remain approximately constant at Base levels. Environmental impact in this scenario appears significant based on the decrease in wildlife habitat improvement, while cost requirements are indicated to be stable between the Base Run and Run 3 scenarios.

Summary of Empirical Results

The Base Run results would indicate that current levels of outputs (timber, range, recreation, water, and wildlife and fish) can generally be produced throughout the planning horizon at current levels of cost. One exception is Region 5; the results indicate that maintaining current output levels would require steadily increasing costs. The same is true to a lesser extent in Region 8.

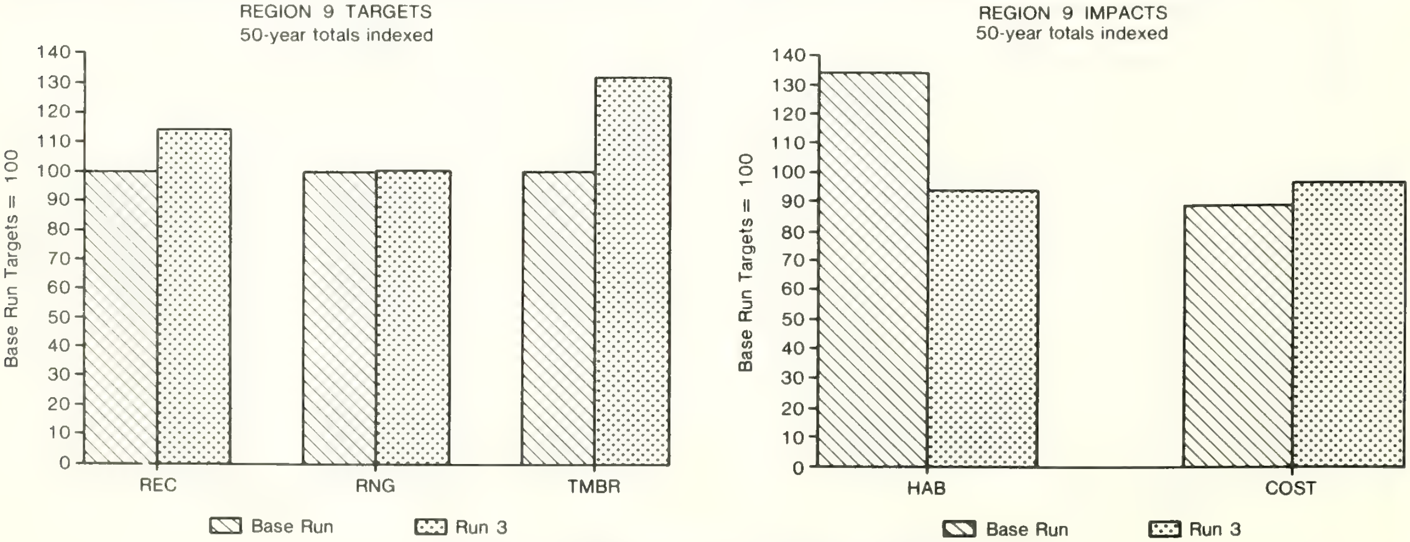


Figure 7.—Fifty-year summary of results: Region 9.

Table 10.—Region 9 Base Run and Run 3 Results.

Output	Base Run			Run 3			
	Output level	Target	Limiting factor	Output level	Target	Demand	Limiting factor
REC1	100	100	+	104	100	100	
REC2	108	100		111	106	106	
REC3	112	100		116	115	115	
REC4	115	100		123	123	123	+
REC5	123	100		129	129	129	+
HAB1	100	100	+	61			
HAB2	125	100		93			
HAB3	144	100		102			
HAB4	155	100		110			
HAB5	147	100		105			
RNG1	94			100	100	100	
RNG2	85			99	99	104	+
RNG3	88			102	102	106	
RNG4	84			101	101	108	
RNG5	86			105	105	111	+
TMBR1	100	100	+	100	100	100	+
TMBR2	118	100		124	120	120	
TMBR3	139	100		155	136	136	
TMBR4	150	100		172	148	148	
TMBR5	158	100		183	157	157	
COST1	87			88			
COST2	85			94			
COST3	91			100			
COST4	89			99			
COST5	93			102			

Timber was typically a limiting factor in the Base Runs only in early time periods (Region 4 was an exception). Range was also typically only limiting in early time periods, except in Region 9 where it was not physically possible to maintain current production levels. Recreation was a limiting factor in the Base Runs in early time periods in Regions 3, 4, 5, 8, and 9. Wildlife and fish were limiting factors early in Regions 1, 3, and 8, and late in Region 8. Habitat improvement was a limiting factor in Regions 1, 2, and 9, typically early in the planning horizon. Water yield was a limiting factor in the Base Runs in Regions 5 and 8.

The results from Run 1 indicate that the demand projections for all outputs in recent RPA studies cannot be simultaneously met in all National Forest System regions within the range of the forest planning alternatives currently developed. This is an important result.

Run 2 developed a production scenario that was feasible, and came as close as possible to the demand projections in the sense that a cardinally weighted (by RPA values) sum of deviations from the demand projections was minimized.

Utilizing the output targets from Run 2, the results from Run 3 indicate that simultaneously achieving this production scenario for all outputs (which, again, is less ambitious than the demand projections) will require substantial increases in cost over current levels—on the order of 20% to 45% throughout the planning horizon. The lone exception is Region 9, where Run 3 costs were very close to current levels.

Effects on sediment from simultaneously meeting the output targets from Run 2 appear to be minimal in all regions, apparently because the forest planning alternatives were generally developed with mitigation of sedimentation as a high priority. The negative effects of the Run 3 production scenario on wildlife habitat improvement are indicated to be a bit more significant in Regions 1 and 9, and, to a lesser degree, Region 2. The other regions all show increases in acres of improved habitat in the Run 3 results.

The potential for increased timber production over time appears to be substantial in all regions, and was a limiting factor in Run 3 only in Regions 5 and 9. This was a result of the discrete nature and definition of the forest planning alternatives currently available. Conversely, in Run 3, range outputs were limiting factors in all regions except Region 5. Recreation was commonly a limiting factor late in the planning horizon, when the targets in Run 3 are relatively high. Wildlife and fish outputs are also commonly a limiting factor after the first time period. Water was indicated to be a critical, limiting factor in all regions. The potential for increased water yield in combination with the other output increases in the Run 3 scenario is not indicated to be promising in any region. It is worth repeating that outputs may be indicated to be limiting factors either because of physical production properties, or because of the way the forest alternatives were defined.

CONCLUSIONS

The introduction posed three questions regarding resource interactions on National Forest System lands. The answers, based on the results just summarized, are as follows:

1. It would appear that current levels of production and environmental conditions can be simultaneously

maintained at current levels of cost in the National Forest System. This conclusion is limited to the particular outputs and environmental indicators studied.

2. Within the range of alternatives generated in the forest planning effort, it does not appear to be feasible for the National Forest System to maintain a constant proportion of national production if that national production is to simultaneously meet the demand projections developed for individual resources in recent assessment analyses. It is impossible to determine if this reflects true physical limits to production, or merely the limits of the forest planning alternatives.

3. The Run 3 scenario, which is less ambitious than the demand projections, is achievable with minimal negative impacts on sediment and with negative impacts on wildlife habitat improvement in Regions 1, 2, and 9, only. Achieving this scenario is indicated to require cost increases, however, in the range of 20% to 45% throughout the planning horizons. These are joint costs that cannot be assigned to any particular outputs or environmental conditions.

Although this analysis provides useful information with respect to the requirements for RPA assessments the present analysis falls short of the ideal interactions assessment. For example, no scenario could be developed that could meet all demand projections simultaneously. But, it could not be concluded that meeting these demands is actually impossible on the National Forest System based on the analysis in this report. While several outputs in the optimum production scenarios developed here were underachieved in terms of projected demands, several others displayed demand overachievements. The range between demand overachievements and underachievements in the production scenarios was often quite wide (overachievements of projected timber demands were particularly conspicuous). Attempts to reduce the slack between demand overachievements and underachievements resulted in infeasibilities. The analysis was limited by the relatively small number and narrow variability of the management alternative options available from the forest planning units.

Another shortcoming in this multilevel resource interactions analysis also involves the data base. Complete sets of study data were often not available for the lower level management alternatives as reported in the forest EIS's (even though consistency and availability of the output data reported in these sources were the main determinants of which data elements were included in the interactions analysis). The extensive use of various estimation techniques and referral to other forest planning records (Baltic and Hof 1987) were required to develop or otherwise obtain missing data. Even then, some alternatives had to be eliminated from the study for lack of necessary data, and not all the outputs considered in the interactions analysis could be included in every regional model. It also became apparent during the data collection process that inconsistencies in both reporting and defining production data for certain outputs exist across forest planning units.

It is clear that different levels of resource planning for National Forest System lands should not be carried out as separate or distinct analyses. The forest plans (EIS's and Proposed Plan), the Assessment of the Forest and Range Land Situation in the United States, and the Recommended Renewable Resources Program are the final products of one comprehensive and integrated planning process. Key concepts in this process are coordination of effort between planning levels, standardization of technology, and systematic development of alternatives. These concepts are discussed here in terms of the interactions assessment, but they relate to the National Forest System planning process as a whole.

This study has demonstrated a need for further refinements in the application of these concepts. First, the outputs need to be standardized across local forest level planning units and upper level analyses (the Assessment and Program) as to their definition and measurement. Second, local management alternatives should be developed in a systematic manner in order to best support multilevel national planning analysis (Hof and Pickens 1986). This would not preclude the achievement of local allocative and economic efficiencies. Finally, combining technological standardization and systematic lower level alternative development in an iterative approach could insure local level allocative efficiencies and global optima. Although the theory for such an approach has been developed (by Dantzig and Wolfe (1961), Kornai and Liptak (1965), and others), its detailed application to a national resource optimization analysis has not been. Hof and Pickens (1986) have suggested the development of such an application and described it in general terms. As they state:

> The Kornai and Liptak (1965) approach (for a two-level problem) involves a "game-theoretical model" between a higher level planning authority (the "center") and a set of sectoral planning units. The center makes an initial, provisional distribution of the "available resources, material, manpower, etc. among the sectors, and at the same time also indicates their output targets." The sectors then rigorously analyze this set of "quotas" and report back "one type of economic efficiency index—the shadow prices derived from programming." The center then modifies the resource and output "quotas" based on this information. By iterating back and forth, a sectoral allocation is arrived at that, within a given tolerance level, equates the shadow prices across sectors, and thereby reaches a global optimum.

In further discussing this application with regard to the problems to be overcome, Hof and Pickens (1986) state:

> There are two principal problems in applying a DW [Dantzig-Wolfe] or FP [Kornai-Liptak] model to a national renewable resource planning problem. First, it would be quite rare for all of the local planning units (such as national forests) to complete their planning efforts simultaneously. Second, the communications network and coordinating authority to implement the repeated iterations necessary in a DW or FP model generally are not present.

Thus, the results here suggest the need for further research into improving and refining the multilevel renewable resource optimization modeling capability.

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While numerous studies have examined the response of a single resource to a specified management activity, quantitative information on multiple resource interactions over large geographic areas (as would be necessary in a national resource interactions analysis) is limited. Thus, relating previous work to the results presented in this report is difficult. The literature reviewed here is provided as background rather than as comprehensive analysis of resource interactions. The study utilized in the Multiple Resource Interactions chapter of the 1980 Assessment will first be reviewed. Then, this review will summarize the findings of selected resource interactions studies (typically involving microlevel production tradeoffs), organized by National Forest System region and type of analysis—biological or economic. Emphasis will be on the empirics of the studies cited.

Resource Interactions Analysis for the 1980 Assessment

Ashton et al. (1980) developed a system of four models to help evaluate alternative national renewable resource programs. The four models were capable of quantifying interactions in terms of cost-effective resource allocations, employment and earnings effects, loss in future options, and changes in social conflict. Feedback from each model could be used to change the input or parameters of the other models. The four models were the National Interregional Multiresource Use Model (NIMRUM), a regional employment and earnings model called the Regional Industrial Multiplier System (RIMS), the Futures Forgone Model, and the Social Conflict Model.

NIMRUM was utilized to quantify potential resource use allocations and resource interactions. This model actually evolved into a series of seven regional linear programming (LP) formulations that were driven by projected resource demands and had minimum cost objective functions. The Nation's 1.7 billion acres of forest and rangeland were broken into 107 potential natural communities (PNCs). The PNC s were further divided into distinct land types or resource units (RUs). Several alternative management levels (intensities) were then developed for each RU. The production plans or resource output activities associated with an alternative management level depended on the response of the RU to the activities, practices, and costs in that management level. The alternative management level scenarios represented the choice variables in this LP. The regional models were formulated to choose one or more alternative per RU. An interdisciplinary team of 200 scientists and land managers was assigned the task of developing each alternative management level's inputs and then quantifying the analogous resource output vectors (technological coefficients). Thirteen outputs were considered in this model. A description of the interactions results using NIMRUM and the data base developed can be found in USDA Forest Service (1981) and Ashton et al. (1980).

Pickens et al. (1987),[2] used two approaches to illustrate the quantification of multiresource interactions using the NIMRUM model and data base. The first application increased demands over time (1985, 1995, 2020) for the market goods (timber harvest and range grazing) to simulate the impact on the intensity and cost of land management. The nonmarket goods were assigned a target level of production. The model was run using the projected market demands both with and without the nonmarket constraints.

In the Rocky Mountain-Great Plains Region, which was used for this first application of NIMRUM, projected demands for both softwood timber and range grazing were met in 1985 and 1995. However, projected demand for range grazing could not be achieved in 2020 until the model was restructured through the reallocation of range grazing demand among the western regions. The largest changes in resource use and environmental effects resulted from increases in range grazing demand.

Where nonmarket output constraints were not applied, herbage and browse increased to 20% above base year levels while wild ruminant grazing decreased to 13% below the 1977 value. The other nonmarket outputs remained relatively constant. In order to meet rising timber and range grazing demands, the number of acres managed intensively more than tripled.

When nonmarket output constraints were applied, dispersed recreation, herbage and browse, and wild ruminant grazing increased beyond 1977 base levels by 22%, 33%, and 23%, respectively. Total costs increased by 20% using the nonmarket constraints. However, the marginal cost for softwood timber was slightly lower under these constraints, suggesting that the production of certain nonmarket outputs (predominantly wild ruminant grazing) are complementary to this output.

The second application of the NIMRUM model involved single and cross product marginal cost analysis to measure resource interactions. Three outputs were assigned three demand levels, and the model was run 27 times to account for all combinations of production levels. The outputs chosen, considered to be the most sensitive within this modeling framework, included softwood timber harvest, domestic AUM production, and wildlife AUM production. The objective function was always formulated to minimize cost, and marginal costs were identified for each product in each run. Product surpluses resulted from several runs, which would indicate that complementary relationships may have existed for certain outputs. The primary analysis in this second approach involved the development of marginal cost curves. The Pacific Southwest region was used for this example. Marginal cost curves were traced for different production levels of the other outputs. The marginal cost curves were not parallel, indicating a nonzero first order interaction, i.e., the effect of timber production on domestic range production depends on

[2]Pickens, James B.; Ashton, Peter G.; Thomas, Michael H. 1987. Use of joint production functions in an LP environment to measure resource interactions. (in process).

the level of wildlife ruminant range production. Also, timber and range seemed to have slightly complementary marginal cost curves (both downward sloping).

Microlevel Production Tradeoffs

Region 1

Bachman (1958) reported on trout streams in Idaho as influenced by logging and forest road construction. Because of the timbering activities, turbidity increased during snowmelt and rapid runoff from storms. Sedimentation increased in both riffles and pools; however, water temperature, volume of flow, and water chemistry showed no change.

In Montana, Marcuson (1968) reported on the effects of stream habitat improvements on Bluewater Creek. Before the projects, sediment was lowest upstream of the project sites and increased progressively downstream. After implementation of three streambank improvement projects, average suspended sediment load was reduced by 1.9 tons/day or 32% nearest the projects, and by 52% and 44% at increasingly further distances downstream from the projects. Trout composition increased from 13% prior to habitat improvements to 37% after improvements.

Schuster and Jones (1985), in western Montana, tested the hypothesis that below cost timber sales (BCTS) and efficient management are not incompatible. Their analysis did not refute this hypothesis. They based their analysis and conclusion on the premise that an assessment of the immediate revenues and costs for specific sales is incomplete. As to the appropriateness of a BCTS, they argue that "It demands a rigorous examination of the role played by specific timber sales and groups of sales in the context of integrated land management, over time and space." The authors suggest that the important measure of management efficiency is discounted net revenue (DNR). In a test case involving two timber sale areas in Montana, they use a mathematical model, the Integrated Resource Planning Model (IRPM), to demonstrate that even with initial BCTS's, positive DNR can result in the long term (NSV stands for Net Sale Value):

Time period	Twin Rocks sale area	Copeland Creek sale area
	—— Thousands	*of dollars ——*
NSV–1	–709	–819
NSV–2	–	617
NSV–3	4,121	14,985
Overall DNR	392	3,467

Region 2

Troendle (1987) studied the effects that thinning young lodgepole pine stands in Colorado and Wyoming have on streamflow. Study results indicated soil water depletion is reduced and water available for streamflow is increased in direct proportion to basal area reduction. The same conclusion holds for evapotransporation loss. However, in dry years, basal area was not related significantly to soil water depletion.

Crouch (1985) studied the effects of clearcutting subalpine forests in central Colorado on wildlife habitat. The undercover plant production and cover increased on all sites (average and moist) with few changes in species composition; plant moisture, protein, and digestibility increased; however, herbivore activity varied between species.

Crouch (1983) studied the effects of commercial clearcutting of aspen on vegetation and wildlife habitat values in southwestern Colorado. After the cuts, the aspen resprouted and there were very few lasting changes in understory vegetation. Much of the aspen was mature, and clearcutting seemed to be an economical method of regenerating these stands. However, cavity-nesters and other species requiring mature forests were adversely affected by the clearcuts. Conversely, large herbivore use was enhanced, although cattle mainly utilized the increased herbage production in these clearcut areas.

Schroeder and Sturges (1975), in Wyoming, reported the effects on the Brewer's Sparrow of spraying the herbicide 2,4–D on big sagebrush to convert the cover type to crop and grasslands. Initially, nesting success was not affected by either the spray or the plant's death. The dried leaves remaining on the dead sagebrush provided sufficient shade and protection. However, bird densities dropped by 67% one year after spraying and by 99% two years after spraying; also no nests were observed in the sprayed areas and all birds seen on the sprayed areas were near small areas of sage that survived the spraying.

Bowes et al. (1986) addressed the issue of below cost timber sales from a capital accounting view of costs and the computation of economically relevant separable costs. They defined separable cost as the increase in current expense, plus the increased depreciation in the forest asset value, that results from including a product in the current management plan. A case study involved analyzing a management program for the Shoshone National Forest in northern Wyoming that included timber, recreation, and wildlife services. Their results demonstrate that efficiency conclusions can be affected substantially by a multiresource perspective.

Along similar lines, Bowes et al. (1984) examined a situation where management for a single resource produces indifferent economic prospects, but, if managed in joint production with another resource, may provide a considerable economic return. Their study involved timber production managed in conjunction with watershed augmentation in the subalpine forests of western Colorado. Results are quite dependent on variables such as terrain, road construction costs, and esthetics.

Brown (1981) analyzed the problem of resource tradeoff considerations in the overall process of developing alternatives for local land management planning. He defined a tradeoff as the relationship between two or more effects of a change in some condition (such as the condition of the forest or a particular resource). Hypothetical resource base situations were defined and empirical results of potential tradeoffs presented. Tradeoffs included individual and dual resource responses to a

single management practice. As an example of some of the empirical results presented in the study, a basal area maintenance of 60 square feet would result in maximum timber yield, fairly low livestock forage production and soil erosion, medium or better scenic quality, high deer habitat quality, and medium squirrel habitat quality and streamflow. Maintaining a basal area of 120 square feet would result in maximum squirrel habitat, low streamflow, soil erosion, livestock forage, and deer habitat quality, and medium sawtimber production and scenic quality.

Bottoms and Bartlett (1975) demonstrated how goal programming can be used to help solve resource allocation problems. They utilized an area in north-central Colorado as a case study. In the process of demonstrating goal programming, they also revealed some resource interactions. They showed that the different users of grazing (cow-calfs, steers, elk, and deer) interact strongly, and that timber interacts with almost all other resources. Dyer et al. (1979) utilized this same model in further investigating goal programming, and in so doing provided additional sensitivity analysis on this case study. They showed that substantial changes in the multiple resource output set from this model were possible by altering production priorities.

Rideout and Hof (1987) demonstrated some game-theoretic approaches to joint cost allocation. Their case study involved a multipurpose forest road in northern Colorado. Their cost data indicate that the cost of building forest roads can be highly dependent on the combination of purposes they serve.

Region 3

Brown et al. (1974) reported on resource interrelationships driven by basal area reduction in the ponderosa pine type of Arizona. Changes in productivity were quantified based on five levels of forest thinning and clearing. Sawtimber, herbage, scenic quality, deer use, streamflow, flood peaks, and sediment were all substantially affected by reductions in basal area.

Patton (1969) studied the effects of timber harvesting on the distribution and abundance of game animals (deer and elk) in the ponderosa pine type of the Castle Creek watersheds near Alpine, Ariz. Both animals' day use per acre was substantially higher on the harvested areas.

Clary and Larson (1971) also reported on elk and deer use in the ponderosa pine type of Arizona on the Beaver Creek watershed. No clear relationships for deer were identified. Elk use was found to be directly related to total herbage production, and inversely related to basal area.

Clary et al. (1968) studied the effect of the accumulation of organic matter above mineral soil (the forest floor) on herbage production on the Beaver Creek watershed in north-central Arizona. Herbage production decreased from over 300 pounds per acre to less than 10 as total forest floor accumulations increased from essentially zero depth to over 2.5 inches.

Brown (1976) analyzed the resource tradeoffs resulting from four alternative harvest regimes. Physical yields of sawtimber, pulpwood, water, forage, and effects on wildlife habitat and esthetics were estimated and reported for each alternative timber management emphasis. The study area was a 562–acre mixed conifer watershed, South Thomas Creek, on the Apache-Sitgreaves National Forest in Arizona. All outputs were substantially affected by the alternative harvest regimes.

O'Connell and Brown (1972) developed product-product production functions for water, timber, and herbage based on several alternative timber cutting regimes on the Beaver Creek watershed of northern Arizona. These timber-driven tradeoff models indicated the supplementary, complementary, and competitive output scenarios obtained within a multiple use framework.

Hof et al. (1985b) studied the joint costs of producing timber and forage in a paper about discrete choices in resource decisionmaking. They determined four points on a constant-cost production possibilities frontier (IIA, IIB, IIC, IID) and a low-intensity reference point (I) using the Coconino National Forest (in central Arizona) FORPLAN model. The results indicate a fairly strong tradeoff between timber and forage:

Alternative	Total timber Bd. Ft.	Total forage AUMs	Minimum cost $1000
IIA	15,333,600	88,991,600	308,440
IIB	30,892,300	85,675,000	308,440
IIC	39,701,200	72,347,800	308,440
IID	41,467,500	52,347,800	308,440
I	16,387,800	19,871,500	205,627

Region 4

Horton and Campbell (1974) reviewed studies in all the southwestern states (Regions 3, 4, and 5) on management of phreatophyte and riparian vegetation, and concluded that "the few riparian treatments performed indicated rather consistent increased water yields were obtained following riparian treatments....In summary a working hypothesis somewhere between 1 and 2 acre-feet of water savings is as close an approximation as possible." Related to these water gains, however, Johnson (1970) had reported that thinning cottonwood for water savings and flood control reduced nesting bird populations as follows:

Treatment	Pairs of nesting birds per 100 acres 1969	1970
Severely thinned (10.1 trees per acre)	583	524
Moderately thinned (26.0 trees per acre)	963	886
No treatment (46.6 trees per acre)	1325	1006

These results demonstrate the importance of considering a complete set of outputs in analyzing resource interactions.

Buckhouse and Gifford (1976) studied the impacts of burning and grazing on the water quality parameters of

phosphorus, potassium, sodium, calcium, and nitrate-nitrogen on sites that had been chained and then seeded to crested wheatgrass in southeastern Utah. Undisturbed areas were left adjacent to the treated areas to act as a control. Following burning, significant increases in potassium and phosphorus were observed at the soil surface. If a hydrologic runoff event occurred, these chemical elements could cause eutrophication of water supplies. No significant treatment changes were observed for the other water quality parameters. No treatment differences because of grazing were detected (stocking rate was 2 ha/AUM).

Region 5

Graves and Burns (1970) reported on the yields of downstream migrant salmonoids before and after logging road construction on the South Fork Casper Creek in Mendocino County, California. Road construction took place in the summer of 1967. Eighty-three percent of the total salmon population and 86% of the total steelhead population died or emigrated from the area affected by road construction. The combined species population of smolts decreased 20%. In 1964, 5% of the fish sampled from the study area were fry. In 1968, 81% were fry. Steelhead smolts were smaller in 1968 while salmon smolts were larger. Salmon fry were smaller in 1968. The increase in length of the salmon smolts may have resulted from a decrease in competition because of the high mortality in 1967. However, the average length of all fish decreased.

The California Resources Agency Task Force (1969) report on the sediment problems in the Trinity River, near Lewiston, concluded that the elimination of flows during reservoir filling and the subsequent release of steady, regulated flows has worked in combination with increased sediment production from adjacent logged lands to drastically reduce habitat quality and salmon populations in this formerly productive fishery.

Kirby et al. (1986) developed a mathematical programming model, the Integrated Resource Planning Model (IRPM), that deals with the interactions between natural resource investments and transportation network investments as the means of generating alternative land management plans. In a case study, IRPM was implemented on the French Creek Basin of the Plumas National Forest in northern California to assess the effects of harvest activities. Their results are complex, but essentially all outputs studied are affected substantially by timber harvest levels.

Region 6

Thomas et al. (1978) reported that the optimum ratio of forage areas to cover areas is 60% to 40% for deer and elk in the Blue Mountains of Oregon. Thus, harvest alternatives that leave less than 40% cover would be expected to reduce deer and elk populations.

The International Pacific Salmon Fisheries Commission (1966) studied the effects of log driving on the salmon and trout populations in the Stellako River, and reported that log jams caused gravel erosion and bark deposition over approximately 8% of sockeye spawning grounds. Subsequent spawners tended to avoid the damaged areas. Laboratory tests indicated that moderate gravel erosion and gouging by individual logs could have destroyed incubating trout eggs.

Lantz (1970) studied the aquatic environmental impacts from logging on the Alsea watershed in Oregon, and concluded that the primary changes caused by logging were the following: an increase in stream temperature, a decrease in dissolved oxygen levels in surface waters during summer when logging debris was present, a decrease in intragravel dissolved oxygen levels, a decrease in the permeability of the intragravel environment when salmon embryos were present, an increase in suspended sediments, and a decrease in the cutthroat trout populations.

Wustenberg's (1954) findings on trout environment impacts from logging in mature Douglas-fir stands in Oregon were as follows: an increase in localized sediment entering the stream because of maintenance and use of logging roads, no pronounced increases in sediment as a result of logging itself, a fine silt consistency for most sediments, a preponderance of sediment concentrations in the upper parts of small tributaries, greater streambed effects from tractor logging than from high lead logging, severe scouring in logged streams during high flows, elimination of cutthroat trout populations in logged streams, adverse effects on aquatic insects for at least one year, and the possibility of reduction in water temperatures through the use of streamside buffer strips.

Wick and Canutt (1978) reported that timber management practices in the Blue Mountains of Washington and Oregon to increase the diversity of wildlife habitats or to mitigate adverse effects of logging on fish and wildlife habitats may cause slight to moderate decreases in timber production.

Schaumburg's (1973) investigation of the effect of water storage of logs on water quality in the Pacific Northwest concluded that soluble leachates (BOD, COD, PBI, solids, and toxicity) from logs floating in water are not a significant water pollution problem. However, sinking bark that can form benthic deposits that exert an oxygen demand may influence the biology of the benthic zone. Also, floating bark may be regarded as esthetically displeasing and could interfere with other beneficial uses of a lake, stream, or estuary.

Fredriksen (1970) reported on the erosion and sedimentation caused by road construction and timber harvest on unstable soils, on three small western Oregon watersheds. No action was taken on one of the watersheds so that it could be utilized as a control. Sedimentation and soil loss increased substantially from the harvesting and roading activities.

Hof et al. (1985a) studied joint costs of producing timber and forage on the Fremont National Forest in southern Oregon. Their results indicate that the portion of total costs that cannot be assigned to either output

(joint cost) varies from 8% to 60%, depending on the output levels—the greater the production of either (or both) outputs, the more interaction can be anticipated.

Region 8

The first four studies discussed in this section are part of a larger work, the "South's Fourth Forest: Alternatives for the Future" (USDA Forest Service 1987), which states:

> The basic purpose of this study of the timber situation in the South is to determine what kind of forest is evolving, what kind of forest will be of greatest benefit to the economy and society, and how can it be achieved.

Implicit in this description is the consideration of several alternative futures or scenarios based on different sets of assumptions concerning the determinants of timber demand and supply. Furthermore, the implications section (Chapter 4) of this work identifies forage production, wildlife and fish abundance, and water quantity as important products and uses of forest lands affected by changes in the forest environment. Four studies quantifying the responses of these resources to the alternative timber management scenarios (Flebbe 1987, Joyce 1987, Ursic 1987, Flather 1987) were performed under a consistent framework, and together constitute a multiresource analysis. The studies were based on the following scenarios.

Baseline.—The level of timberland management is much more intensive than that practiced today. By 2030, the area in pine plantations is nearly doubled; large areas of mixed pine-hardwoods and upland hardwoods are converted to pine. Planting or conversion of these areas to pine would require investments of $2.7 billion, with most of the investment occurring within the next 15 years. Substantial increases in timber yields and in the intensity of management are also assumed for large areas of pine plantations. Thus, the base projections reflect what would happen if there continues to be progress in forestry in the South—including continued expansion in the technical and financial assistance, protection, research, education, and management programs that have brought about the improved forestry situation in the past.

Increased stumpage costs.—The future, as described by the basic assumptions and other specified and implied assumptions in this report, is modified by increasing stumpage prices above the base projections by 5% by 1990, 10% by 2000, 15% by 2010, and 20% by 2020.

Reduced timberland area.—The future, as described by the basic assumptions and other specified and implied assumptions in this report, is modified by reducing the projected area in timberland in the South by 2 million acres in 1990, 5 million acres in 2000, and 11 millions acres in 2030.

Reduced timber growth.—The future, as described by the basic assumptions and other specified and implied assumptions in this report, is modified by reducing by 25% the net annual growth on pine plantations, natural pine, and mixed pine-hardwood stands shown in the empirical yield tables used in developing the base-level projections.

Reduced national forest harvest.—The future, as described by the basic and other specified and implied assumptions in this report, is modified by reducing timber harvests on the national forests to 8.1 billion board-feet in 1990 and maintaining this level through 2030.

Economic opportunities on private timberlands.—The future, as described by the basic assumptions and other specified and implied assumptions in this report, is modified by assuming that all the economic opportunities for increasing timber supplies on timberland in private ownerships that yield 4% or more net of inflation or deflation would be utilized.

The softwood roundwood timber supply projections for these six scenarios are reproduced in table A1.

Flebbe (1987) reported on coldwater fish population responses to the timber scenarios on a study area that included portions of Virginia, North Carolina, South Carolina, and Georgia. Discriminant function analysis was used to predict trout densities within watersheds based on land use and cover type and water quantity. Data on water flow, land use, land-cover type, and trout population densities were derived for each watershed using various sampling techniques. The discriminant function model captured the statistical relationships between trout density and significant land use/cover and water quantity variables. Then, the analogous variables from each alternative timber scenario were applied to this model to derive a schedule of trout production (table A2). Generally, fish populations decrease in response to increased urbanization and land use shifts that decrease mature forest areas.

Joyce (1987) reported on forage production responses to the timber scenarios. She used several modeling approaches to quantify forage production for three different land types—forestland, pasture, range—and all lands. The analysis was driven by the land use and timber inventory projections as reflected in the alternative timber management scenarios. The study area encompassed 12 states divided into two regions, Southcentral and Southeast. Climatic data, past management, and timber stand characteristics were related to forage production. No forage management to timber management feedback existed in the analysis that would affect timber outputs: "The forage analyses predict what might occur when forage is not the primary resource being managed." Tables A3 through A6 show that land use shifts out of pasture/range significantly decrease forage, while shifts to the more open canopy of planted pine increase forage production.

Ursic (1987) reported on water response to the timber scenarios. Statistical regression models were developed to estimate water yields using precipitation, land use, and cover type as independent variables. Certain shortcomings in this modeling approach required a supplemental technique, referred to as "response modeling." Both models were then utilized to develop a water yield

schedule by alternative timber scenario. Different yields were obtained over all periods and alternatives using the two methodologies. An adjustment technique was then developed to derive one water yield figure. Table A7 illustrates the water yield (in area inches) response to alternative management scenarios; this yield table relates to the entire 12–state study area. A small increase in water yield is indicated, reflecting the conversion of land from forest and pasture to urban use.

Flather (1987), reporting on wildlife responses to the timber scenarios, utilized discriminant function analysis to derive statistical relationships between land use and cover type and the relative abundance of indicator wildlife species. The analysis covered the 12–state study area and was performed on a county-by-county basis. Wildlife species modeled included white-tailed deer, wild turkey, and red-cockaded woodpecker. While the wildlife models were based on county level information, the alternative timber management scenarios described changes in land base statistics at the regional and state level. A technique referred to as "raking" was utilized to modify the land use and cover type changes reflected in the alternative scenarios to a county level basis. The wildlife responses to the alternative timber scenarios are shown in tables A8 through A10. Wildlife decreases reflect the land use changes such as increased urbanization and increased young planted pine stands.

Wright et al. (1976) reported the effects of prescribed burning on erosion, runoff, and water quality in Texas. Juniper was dozed into piles and then burned. Twelve watersheds representing three slope classifications were involved in this study. Two treated and two control areas were chosen for each slope class. No significant effects were observed on the level areas. Water quality was lowered by treatment on moderate slopes. Total effects were so adverse on steep slopes that it was recommended that these areas be left in their natural state.

Hof and Field (1987) studied part of the Talladega National Forest in Alabama, testing a variety of joint cost allocation approaches. In the process of carrying out this study, some resource interactions information was also provided. Cost estimates were determined with a FORPLAN model for all combinations of timber, recreation, and quail in five different "alternative" output sets (varying timber only). The results indicated that the costs were strongly interactive. This study also determined "core conditions"—rational bounds on the limits of how much cost could tenably be assigned to each output. A large portion of total cost was joint—the lower bounds and upper bounds are widely disparate. Allocation of this joint cost is thus arbitrary.

Region 9

Hornbeck and Reinhart (1964) studied the effects of logging steep terrain on water quality and soil erosion. The study site was the Fernow Experimental Forest in the mountains of West Virginia. The study compared commercial clearcutting with no regard for environmental impacts to intensive selection cutting with careful planning to protect environmental quality. Streams in the commercial clearcut displayed maximum turbidities of 56,000 ppm, while the maximum turbidity in the watershed with the intensive selection cutting was 25 ppm.

Brown et al. (1977) reported the effects of recreational use on forest soils and vegetation. The study area included eight camping and picnic sites in forest stands in Rhode Island. The stands were typical of those found throughout southern New England. Recreation use resulted in significant compaction of soils, which decreased water infiltration rates, reducing vegetation growth and increasing surface runoff. The runoff, in turn, eroded both surface soils and litter which led to nutrient depletion. Not only were ground and understory vegetation affected but also the radial and height growth of some tree species such as scarlet oak and white pine were reduced. The trampling of ground cover vegetation in recreation areas was perhaps the most dramatic impact.

Moulding (1976) studied the impact of insecticide use on forest birds. Bird censuses were conducted before and after a gypsy moth control program in New Jersey. The control program involved the aerial spraying of a low-persistence insecticide (Sevin). Forest bird abundance fell by 55% 8 weeks after spraying. Bird diversity declined with the spraying, which affected some species more than others. One year later, bird populations continued to be depressed at a level 45% lower than the prespray period. There was no evidence of bird mortality in the study area. Thus, the actual mechanism that caused declines in abundance and diversity are not known. Hypotheses include reductions in food sources causing migration outside the area to feed, reduced reproductive success, and shifts in site loyalty.

Table A1.—Simulated effects of selected futures on projected softwood roundwood supplies (million cubic feet) in the South.

Item Year	Baseline	Increased stumpage cost	Reduced timberland area	Reduced timber growth	Reduced NFS harvest	Economic opportunities on private
	(All projections at equilibrium levels)					
Forest industry						
Southeast						
1984	679	679	680	668	679	679
1990	771	771	772	719	770	744
2000	980	962	982	863	985	948
2010	1115	1080	1115	923	1112	1081
2020	1237	1201	1243	1051	1253	1213
2030	1334	1289	1336	1117	1341	1314
South-central						
1984	1053	1053	1053	1042	1053	1053
1990	1130	1115	1132	1060	1140	1100
2000	1259	1224	1261	1086	1281	1224
2010	1378	1327	1386	1120	1394	1344
2020	1456	1406	1471	1179	1482	1429
2030	1522	1477	1416	1263	1542	1514
Other private						
Southeast						
1984	1526	1526	1526	1534	1526	1526
1990	1472	1461	1472	1494	1458	1506
2000	1450	1428	1448	1480	1445	1519
2010	1432	1397	1426	1429	1431	1530
2020	1422	1379	1414	1331	1437	1528
2030	1427	1378	1416	1268	1441	1534
South-central						
1984	1308	1308	1308	1315	1308	1308
1990	1351	1337	1350	1367	1362	1392
2000	1360	1329	1353	1388	1390	1430
2010	1343	1297	1328	1343	1371	1438
2020	1293	1237	1265	1244	1327	1410
2030	1239	1183	1198	1142	1268	1377
National Forest						
Southeast						
1984	45	45	45	45	45	45
1990	46	46	46	46	46	46
2000	48	48	48	48	46	48
2010	58	58	58	58	46	58
2020	72	72	72	72	58	72
2030	77	77	77	77	62	77
National Forest						
South-central						
1984	139	139	140	140	139	139
1990	165	165	165	165	141	165
2000	205	205	205	205	135	205
2010	221	221	221	221	135	221
2020	259	259	259	259	135	259
2030	289	289	289	289	135	289
Other public						
Southeast						
1984	85	85	85	85	85	85
1990	100	100	100	100	100	100
2000	104	104	104	104	104	104
2010	106	106	106	106	106	106
2020	109	109	109	109	109	109
2030	114	114	114	114	114	114
South-central						
1984	50	50	50	50	50	50
1990	55	55	55	55	55	55
2000	61	61	61	61	61	61
2010	61	61	61	61	61	61
2020	61	61	61	61	61	61
2030	61	61	61	61	61	61

Source: USDA Forest Service (1987).

Table A2.—Trout density (trout/acre of stream) for Southeastern cold-water watersheds under baseline and alternative scenarios.

	Baseline	Increased stumpage cost	Reduced timberland area	Reduced timber growth	Reduced NFS harvest	Economic opportunities on private
1985	173	173	173	173	173	173
1990	176	176	178	177	178	174
2000	163	162	173	168	168	156
2010	133	130	156	135	129	127
2020	128	124	155	128	119	126
2030	126	122	155	123	119	124

Source: Flebbe (1987).

Table A3.—Forage production (million tons) on all lands for baseline and alternative scenarios for Southeast (SE) and South-central (SC) regions.

Year	Baseline	Increased stumpage cost	Reduced timberland area	Reduced timber growth	Reduced NFS harvest	Economic opportunities on private
			South-central region			
1985	71.57	71.60	70.72	71.52	71.57	71.60
1990	70.99	71.12	70.27	71.20	70.99	71.57
2000	70.01	70.18	69.64	70.56	69.96	70.64
2010	68.45	68.70	68.56	69.31	68.35	69.31
2020	66.56	66.86	67.20	67.75	66.43	67.48
2030	64.85	65.09	65.91	66.20	64.69	65.70
			Southeast region			
1985	53.77	53.81	53.54	53.67	53.78	53.81
1990	52.69	52.76	52.48	52.78	52.72	53.24
2000	52.72	52.83	52.60	53.40	52.79	53.13
2010	52.41	52.50	52.46	53.52	52.49	52.88
2020	51.82	51.85	52.00	53.28	51.84	52.26
2030	50.51	50.44	50.84	52.35	50.50	50.81

Source: Joyce (1987).

Table A4.—Forage production (million tons) on forestland for baseline and alternative scenarios for Southeast (SE) and South-central (SC) regions.

Year	Baseline	Increased stumpage cost	Reduced timberland area	Reduced timber growth	Reduced NFS harvest	Economic opportunities on private
			South-central region			
1985	7.076	7.108	7.077	7.024	7.076	7.108
1990	7.740	7.864	7.666	7.953	7.743	8.322
2000	9.015	9.186	8.807	9.561	8.967	9.648
2010	9.570	9.822	9.310	10.429	9.466	10.430
2020	9.875	10.170	9.606	11.062	9.738	10.789
2030	9.736	9.975	9.459	11.080	9.572	10.576
			Southeast region			
1985	8.846	8.875	8.846	8.736	8.846	8.875
1990	8.848	8.920	8.815	8.943	8.875	9.398
2000	9.342	9.447	9.257	10.013	9.409	9.745
2010	9.500	9.580	9.401	10.603	9.566	9.962
2020	9.457	9.487	9.377	10.924	9.482	9.901
2030	8.935	8.873	8.862	10.781	8.929	9.233

Source: Joyce (1987).

Table A5.—Forage production (million tons) on pasture for baseline and alternative scenarios for Southeast (SE) and South-central (SC) regions.

Year	Baseline	Increased stumpage cost	Reduced timberland area	Reduced timber growth	Reduced NFS harvest	Economic opportunities on private
			South-central region			
1985	49.54	49.54	48.78	49.54	49.54	49.54
1990	48.52	48.52	47.96	48.52	48.52	48.52
2000	46.43	46.43	46.35	46.43	46.43	46.43
2010	44.58	44.58	45.00	44.58	44.58	44.58
2020	42.78	42.78	43.72	42.78	42.78	42.78
2030	41.58	41.58	42.94	41.58	41.58	41.58
			Southeast region			
1985	32.72	32.72	32.53	32.72	32.72	32.72
1990	32.40	32.40	32.27	32.40	32.40	32.40
2000	32.27	32.27	32.28	32.27	32.27	32.27
2010	32.01	32.01	32.19	32.01	32.01	32.01
2020	31.66	31.66	31.96	31.66	31.66	31.66
2030	31.09	31.09	31.52	31.09	31.09	31.09

Source: Joyce (1987).

Table A6.—Forage production (million tons) on range for baseline and alternative scenarios for Southeast (SE) and South-central (SC) regions.

Year	Baseline	Increased stumpage cost	Reduced timberland area	Reduced timber growth	Reduced NFS harvest	Economic opportunities on private
			South-central region			
1985	14.96	14.96	14.87	14.96	14.96	14.96
1990	14.74	14.74	14.65	14.74	14.74	14.74
2000	14.56	14.56	14.49	14.56	14.56	14.56
2010	14.30	14.30	14.25	14.30	14.30	14.30
2020	13.91	13.91	13.87	13.91	13.91	13.91
2030	13.54	13.54	13.51	13.54	13.54	13.54
			Southeast region			
1985	12.21	12.21	12.16	12.21	12.21	12.21
1990	11.44	11.44	11.39	11.44	11.44	11.44
2000	11.11	11.11	11.06	11.11	11.11	11.11
2010	10.91	10.91	10.87	10.91	10.91	10.91
2020	10.70	10.70	10.67	10.70	10.70	10.70
2030	10.48	10.48	10.46	10.48	10.48	10.48

Source: Joyce (1987).

Table A7.—Water yield (area inches) for baseline and alternative scenarios for entire Southern study area.

Year	Baseline	Increased stumpage cost	Reduced timberland area	Reduced timber growth	Reduced NFS harvest	Economic opportunities on private
1985	15.64	15.64	15.63	15.64	15.64	15.64
1990	15.64	15.65	15.67	15.65	15.64	15.58
2000	16.05	16.06	16.17	16.10	16.05	15.94
2010	16.35	16.36	16.53	16.44	16.34	16.26
2020	16.48	16.47	16.76	16.63	16.47	16.38
2030	16.57	16.55	16.94	16.77	16.56	16.47

Source: Ursic (1987).

Table A8.—Red-cockaded woodpecker responses (counties with RCW present) to baseline and alternative scenarios for Southeast (SE) and South-central (SC) regions.

Year	Baseline	Increased stumpage cost	Reduced timberland area	Reduced timber growth	Reduced NFS harvest	Economic opportunities on private
			Southeast region			
1985	115	114	115	114	115	114
1990	93	92	94	88	93	97
2000	43	43	43	37	43	50
2010	36	36	37	36	36	35
2020	35	35	35	35	35	35
2030	35	35	35	35	35	35
			South-central region			
1985	56	56	56	56	56	56
1990	50	50	50	50	50	50
2000	49	49	48	51	50	44
2010	51	51	50	51	51	50
2020	49	50	47	49	50	49
2030	47	48	41	46	50	48

Source: Flather (1987).

Table A9.—Wild turkey density (turkeys/mi^2) responses to baseline and alternative scenarios for Southeast (SE) and South-central (SC) regions.

Year	Baseline	Increased stumpage cost	Reduced timberland area	Reduced timber growth	Reduced NFS harvest	Economic opportunities on private
			Southeast region			
1985	5.3	5.3	5.3	5.3	5.3	5.3
1990	5.2	5.1	5.1	5.1	5.1	5.2
2000	4.9	4.9	4.8	4.9	4.9	5.0
2010	4.7	4.7	4.5	4.6	4.6	4.7
2020	4.7	4.8	4.5	4.7	4.7	4.8
2030	4.8	4.9	4.6	4.9	4.8	5.0
			South-central region			
1985	6.6	6.6	6.6	6.6	6.6	6.6
1990	5.8	5.8	5.8	5.8	5.8	5.7
2000	5.5	5.5	5.6	5.5	5.5	5.6
2010	5.8	5.8	5.8	5.8	5.8	5.8
2020	6.0	6.1	6.1	6.1	6.0	6.2
2030	6.4	6.6	6.5	6.5	6.3	6.8

Source: Flather (1987).

Table A10.—White-tailed deer density (deer/mi^2) responses to baseline and alternative scenarios for Southeast (SE) and South-central (SC) regions.

Year	Baseline	Increased stumpage cost	Reduced timberland area	Reduced timber growth	Reduced NFS harvest	Economic opportunities on private
			Southeast region			
1985	17.0	17.0	17.0	17.0	17.0	17.0
1990	16.9	16.9	17.0	16.9	16.9	16.8
2000	16.6	16.5	16.9	16.4	16.6	16.6
2010	15.8	15.7	16.4	15.8	15.8	15.5
2020	15.1	14.8	15.7	15.1	15.1	14.8
2030	14.5	14.3	15.2	14.5	14.4	14.3
			South-central region			
1985	17.6	17.6	17.6	17.6	17.6	17.6
1990	16.9	16.9	16.9	16.9	16.9	16.8
2000	16.5	16.6	16.6	16.5	16.6	16.7
2010	16.0	16.2	16.1	15.9	16.0	16.4
2020	14.3	14.9	14.3	14.3	14.2	15.0
2030	13.6	14.4	13.3	13.7	13.5	14.4

Source: Flather (1987).

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United States
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Forest Service

Rocky Mountain
Forest and Range
Experiment Station

Fort Collins,
Colorado 80526

General Technical
Report RM-157

The Vegetation of the Grand River/Cedar River, Sioux, and Ashland Districts of the Custer National Forest: A Habitat Type Classification

Paul L. Hansen and George R. Hoffman

Abstract

A vegetation classification was developed, using the methods and concepts of Daubenmire, on the Ashland, Sioux, and Grand River/Cedar River Districts of the Custer National Forest. Of the 26 habitat types delimited and described, eight were steppe, nine shrub-steppe, four woodland, and five forest. Two community types also were described. A key to the habitat types and some of the changes resulting from disturbances of the vegetation also are included.

Cover Photo.—Scattered *Pinus ponderosa* stands, Ashland District, Custer National Forest.

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The Vegetation of the Grand River/Cedar River, Sioux, and Ashland Districts of the Custer National Forest: A Habitat Type Classification[1]

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Contents

The Vegetation of the Grand River/Cedar River, Sioux, and Ashland Districts of the Custer National Forest: A Habitat Type Classification

Paul L. Hansen and George R. Hoffman

Introduction

The vegetation of the northern Great Plains occupies an area of complex physiographic features, and the diverse plant communities include steppe, shrub-steppe, woodlands, and forests. Land managers and scientists alike have long recognized the need to classify plant communities and land units, and they have developed numerous forest and range type classifications over the years. Many such classifications have emphasized current plant communities (cover types) regardless of their successional status, or they have focused on a single-purpose objective, such as the management of land for producing livestock forage (range sites). Such classifications either have ignored potential climax vegetation or have evolved in such a way as to show either a perceived or a real lack of relationship to potential climax vegetation (Daubenmire 1984, Hoffman 1984, Pfister 1986). Pfister (1986) indicated the original concept of using potential climax vegetation as the foundation is very similar between the habitat type and range site classifications. However, the operational procedures for range site identification have evolved much closer to a direct physical site factor approach than to one based on potential vegetation.

In 1952, Daubenmire described a habitat type classification for the forested areas of northern Idaho and eastern Washington. Later Daubenmire and Daubenmire (1968) refined this classification of forest lands and published detailed data on the vegetational composition of each stand. In 1970, Daubenmire classified similarly lands supporting steppe vegetation in Washington. Accepting and adapting the habitat type system of classification for nonforested lands has been slower than for forested lands.

The present study was started in 1981 with the following objectives:

1. Develop a habitat type classification for lands supporting steppe, shrub-steppe, woodland, and forest vegetation of the Grand River/Cedar River, Sioux, and Ashland Districts of the Custer National Forest.
2. Relate the habitat types to soils and climatic data as closely as possible.
3. Relate Custer National Forest habitat types to those of similar studies in this and adjacent regions.

This habitat type classification, completed in 1985, is based on concepts and methods developed by Daubenmire and Daubenmire (1968), Daubenmire (1970), Hoffman and Alexander (1976, 1980, 1983, 1987), and Hansen et al. (1984).

Previous Habitat Type Studies

While many earlier vegetation studies in the northern Great Plains region emphasized management or carried an autecologic emphasis, a few recent studies have employed the habitat type concept in classifying land units. Hansen et al. (1984) described and classified 10 habitat types involving steppe, shrub-steppe, and woodland vegetation of Theodore Roosevelt National Park, North Dakota. Seven of these habitat types also occur in the present study area. In a study along the Missouri River breaks of north-central Montana, Mackie (1970) described 12 habitat types, four of which were recognized in this study. Hoffman and Alexander (1976) identified 14 forest habitat types in the Bighorn Mountains of north-central Wyoming, three of which also occur in the present study area. In their study of forest habitat types of Montana, Pfister et al. (1977) sampled only a few stands in southeastern Montana; however, three of their habitat types dominated by *Pinus ponderosa* also were present in this study. In a study of the forest habitat types of the Crow and Northern Cheyenne Indian Reservations in eastern Montana, Cooper and Pfister (1984) identified 25 habitat types, three of which were recognized in this study. In the steppe and shrub-steppe areas of western Montana, Mueggler and Stewart (1980) identified 29 habitat types, four of which were identified in this study. Of the 19 habitat types Jorgenson (1979) described for the Yellow Water Triangle of Montana, at least four occur in the area covered by this study. In a recently completed study, Hoffman and Alexander (1987) identified seven *P. ponderosa*-dominated habitat types and one *P. ponderosa*-dominated community type in the Black Hills. Two of these habitat types also occur in this study, and the community type was identified as a habitat type in the present study.

Study Area

Physiography and Geology

The Grand River/Cedar River, Sioux, and Ashland Districts of the Custer National Forest (fig. 1) lie within the unglaciated Missouri Plateau section of the Great Plains Province (Fenneman 1931, Montagne et al. 1982). The Missouri Plateau is characterized as an upland plain interrupted by tablelands, drainageways, streams, and rivers. The dominant feature of the region is the rolling, terrace-like, steppe-dominated plains consisting of soft-

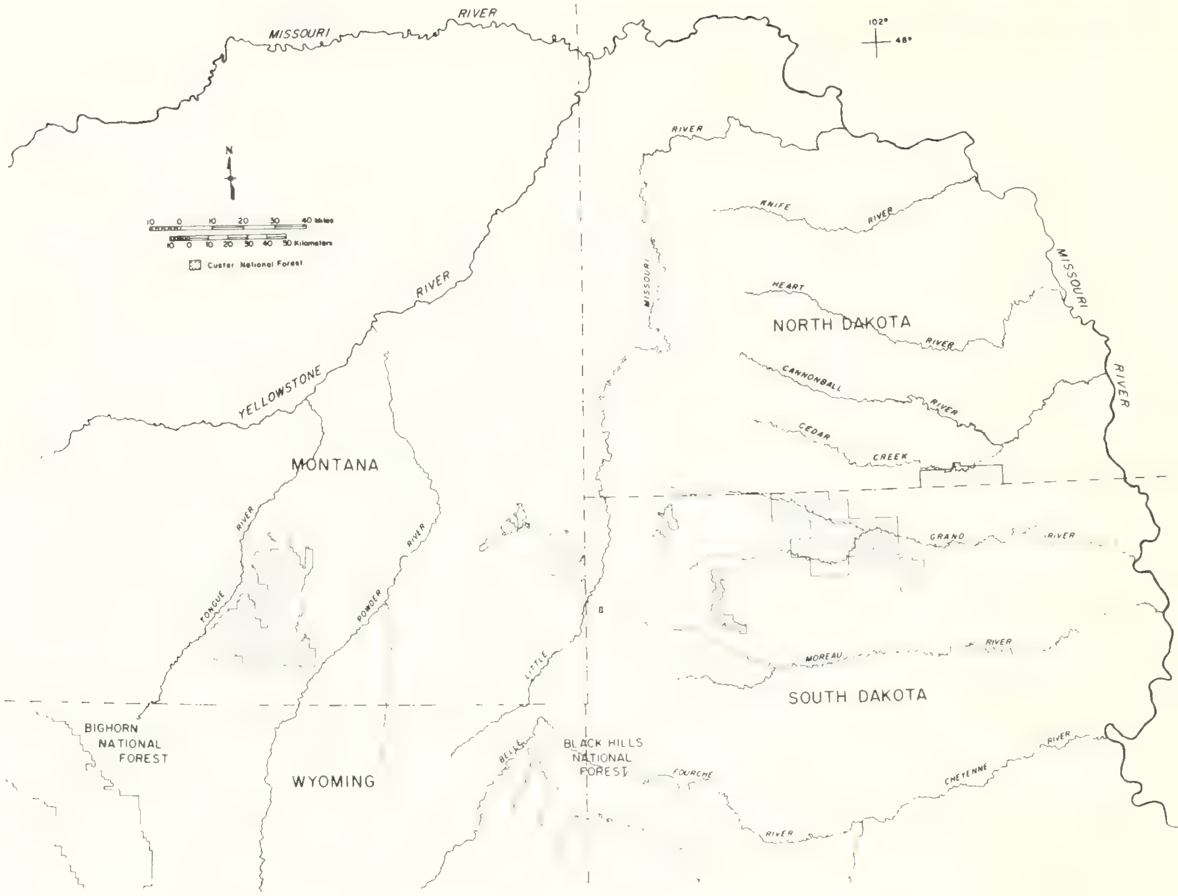

Figure 1.—Custer National Forest showing locations of the Grand River/Cedar River, Sioux and Ashland Districts.

ly consolidated and cross-bedded silt, clay, sand, and hard porcelainite shale of the Cretaceous and Tertiary Periods. Also present are alluvial deposits laid down during the Quarternary Period. Along drainageways, the deposits form smooth, coalescing alluvial fans, foot slopes, and stream terraces varying in width from 1,312 feet (400 m) to 3.1 miles (5 km). Most tablelands of the area are capped with resistant sandstone and form prominent features of the landscape.

The Grand River Ranger District administers the Grand River National Grassland in Perkins and Corson Counties of South Dakota, and the Cedar River National Grassland in Sioux and Grant Counties of North Dakota. The landscape of the Grand River District is an upland plain moderately dissected by streams and entrenched drainageways. Relief is gently rolling to steep in much of the region, with a few prominent buttes and ridges (fig. 2). The main drainages are the Grand River and Cedar Creek, which flow easterly to the Missouri River.

The Sioux District is located in Carter County of southeastern Montana and Harding County of northwestern South Dakota. Characteristic of the region are eight land units that rise 328 to 984 feet (100 to 300 m) above the surrounding plain. These are the North Cave Hills, South Cave Hills, Slim Buttes, East Short Pines, and West Short Pines in South Dakota, and the Long Pikes, Ekalaka Hills, and Chalk Buttes in Montana (fig. 3). All are sandstone buttes and hills that are geologic remnants of the Fort Union Formation and the Hell Creek Formation of the Tertiary Period overlying the Cretaceous tablelands of eastern Montana and western South Dakota (Montagne et al. 1982, Stone et al. 1983). The main drainages are the Grand and Moreau Rivers that flow eastward and the Little Missouri River that flows northward to the Missouri River.

The Ashland District lies between the Tongue River and the Powder River in Rosebud and Powder River Counties of southeastern Montana. The surface geology of the region is comprised of the Tongue River Member of the Fort Union Formation. It consists of nearly level bedded, weakly consolidated soft sandstones, silty sandstones, clayey shales, and lignite beds (Warren 1959). Large areas of the lignite beds have burned, and heat from the burning lignite has baked and oxidized adjacent shale beds to produce brittle, reddish-colored iron-oxide porcelainite, locally called scoria and clinker beds.

The soft shales and sandstones of the Fort Union Formation erode readily and have formed intricately dissected plateau topography with a complex of high and intermediate bench levels. Common landscape features include badlands, sandstones, shale escarpments, and scoria buttes with highly irregular topography. South-facing slopes generally have more exposure of shale and sandstones and a larger number of drainages. The scoria

or porcelainite beds form a distinct topography with isolated irregular buttes and some slump-like relief with an underdeveloped drainage. Stream valleys have a complex pattern of bottom lands, low terraces, and local alluvial fans. The main drainages are the Tongue River and the Powder River, which flow northward to the Yellowstone River.

Climate

The relatively xeric continental climate of the region is characterized by long, cold winters and short, warm summers. The January mean is 17.4° F (–8.1° C), and the July mean is 71.6° F (22° C). In a normal year, about 75% of the annual precipitation falls during the growing season from April through September; approximately 50% falls during April, May, and June (fig. 4). The mean annual precipitation ranges from approximately 13 inches (330 mm) at Ashland, Mont., to 16.5 inches (420 mm) at Bison, S. Dak. Topography of the Ashland District influences the precipitation pattern. Annual precipitation varies from about 20 inches (508 mm) in the south-central part to 13 inches (330 mm) along the south, east, and west boundaries of the district and 15

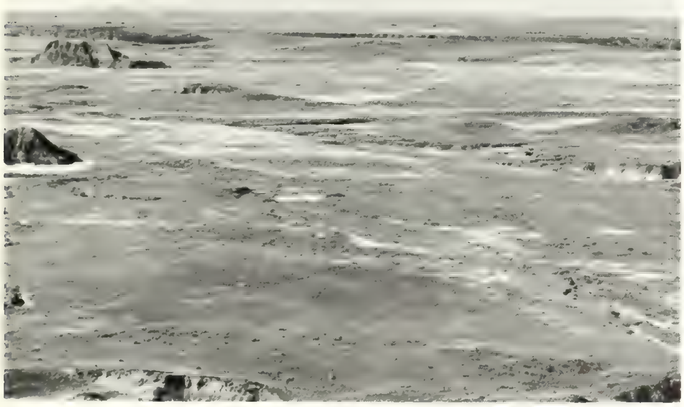

Figure 2.—Characteristic steppe-dominated landscape of the Grand River/Cedar River District, Custer National Forest.

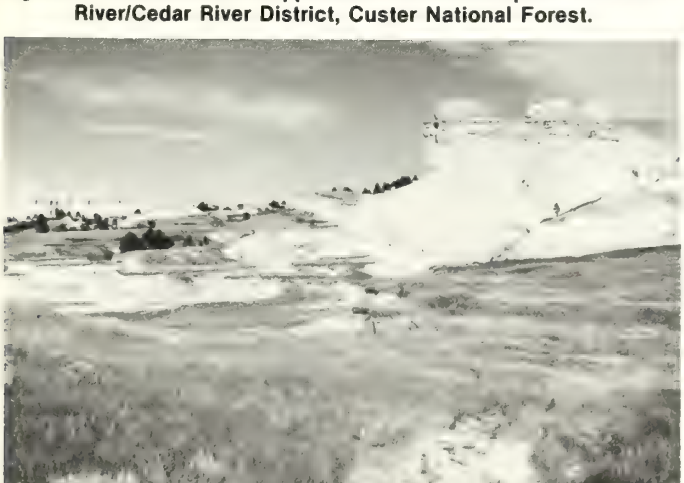

Figure 3.—Characteristic landscape of the Sioux District, Custer National Forest.

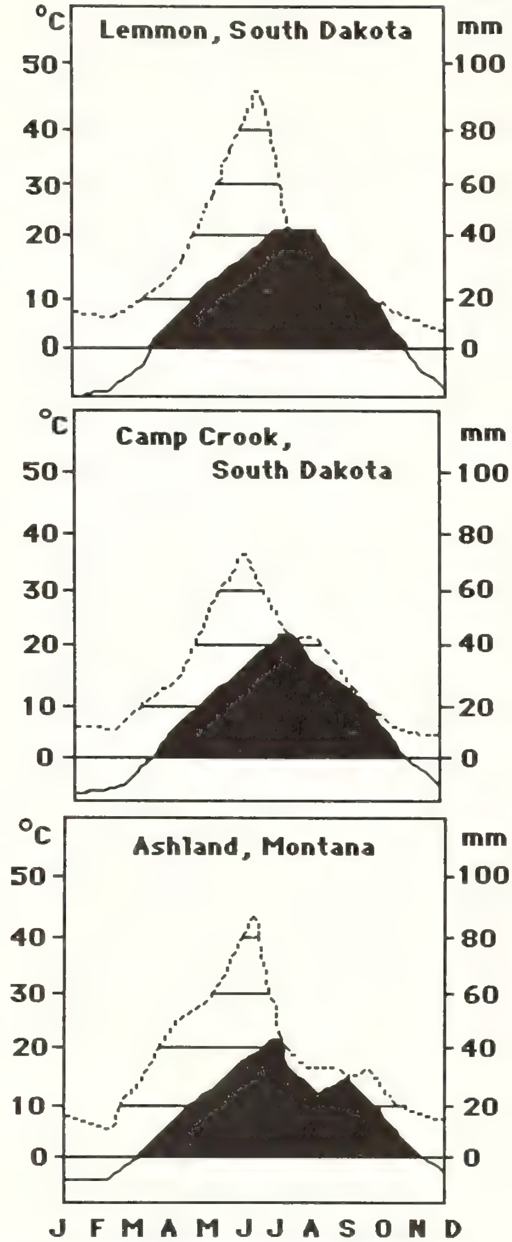

Figure 4.—Average monthly temperature and precipitation at three locations in or near the Custer National Forest, Montana and South Dakota. Temperature (°C) is indicated by the broken line, precipitation (mm) by the solid black area.

inches (381 mm) along the northern boundary. Similar variations in precipitation also occur in the Sioux District (U.S. Department of Commerce 1965a, 1965b).

Ecological Terms and Concepts

Concepts and terminology in this report are consistent with usage proposed by Daubenmire (1968a, 1978) and used in numerous studies of habitat types.[3]

[3] *These include: Alexander 1985; Alexander et al. 1984a, 1984b; Alexander et al. 1986; Cooper and Pfister 1984; Daubenmire 1970; Daubenmire and Daubenmire 1968; DeVelice et al. 1986; Hanks et al. 1983; Hansen et al. 1984; Hironaka et al. 1983; Hoffman and Alexander 1976, 1980, 1983, 1987; Mauk and Henderson 1984; Moir and Ludwig 1979; Mueggler and Stewart 1980; Pfister et al. 1977; Pfister and Arno 1980; Steele et al. 1981, 1983; Youngblood and Mauk 1985.*

"Climax vegetation" is that which has attained a steady state with its environment, and in the absence of excessive disturbance, species of climax vegetation appear to maintain their population sizes. "Seral vegetation" is that which has not theoretically attained a steady state, and current populations of some species are being replaced by other species. "Habitat type" is that land area that supports, or has the potential of supporting, the same primary climax vegetation.

The following classification of climax vegetation was first proposed by Tansley (1935) and later modified by Daubenmire (1952). "Primary climaxes" develop on habitats where recurring disturbance is not a factor influencing the structure or composition of the vegetation. "Climatic climax" vegetation develops on normal topography with fairly deep, well-drained, loamy soil. Where topography or soil exert sufficient influence to produce a self-perpetuating, steady-state vegetation distinct from the climatic climax, the term "topographic climax" or "edaphic climax," respectively, is used. Where special topographic conditions also favor the development of edaphic conditions distinct from the normal and the climax vegetation is distinct from the climatic climax, the term "topoedaphic climax" is used. Where recurring disturbances, such as grazing or fire, exert the predominant influence in maintaining the structure and composition of the steady-state vegetation, the term "disclimax" is used. A "zootic climax" is stable vegetation that is distinct as a result of heavy recurring use by animals. "Fire climax" is stable vegetation that is distinctive as a result of periodic burning. Disclimaxes—the zootic climax or fire climax—are not the basis for recognizing habitat types.

"Plant association" is a term used to group together all those stands of climax vegetation that occur in environments so similar that there is much floristic similarity throughout all layers of the vegetation. For example, numerous stands of the *Stipa comata/Carex filifolia* plant association occur. The units of land on which these occur represent the *S. comata/C. filifolia* habitat type. This latter nomenclature is useful, because throughout the study region, most parcels of land support vegetation in a successional (seral) stage. Where those land units are recognized to be part of the *S. comata/C. filifolia* habitat type, they are so categorized. Thus, a multitude of variation in the matrix of vegetation over the landscape theoretically can be categorized into a manageable number of units. The categories are defined to represent, as closely as possible, the natural biotic potential (climaxes) of the region. "Community type" is a plant community of unknown successional status. In most cases, community types are seral and often long-lived. Thickets of *Symphoricarpos occidentalis*-dominated vegetation are interspersed through the vegetation matrix of several habitat types of Theodore Roosevelt National Park (Hansen et al. 1984). Because these stands probably are seral, though long-lived, they were considered a community type. The structure of vegetation can be thought of in terms of "unions," single species of high abundance and distinctive ecology or a rather well-defined group of species that occur together in approximately the same narrow range of environmental variation in the landscape. Unions may be distinct physiognomically. "Synusiae" or "layers" have closely similar definitions in the ecologic literature.

As it is theoretically the end result of succession, the climax plant community is an expression of the biotic potential of the site where it occurs. Each habitat type is a relatively narrow segment of environmental variation and is defined by a certain potential for vegetational development. Although one habitat type may support a variety of disturbance-induced or seral plant communities, the potential product of vegetational succession anywhere within one habitat type is theoretically the same climax community.

If succession can be recognized and understood, the long-term product of succession is the climax or steady-state community. Insofar as this community is self-perpetuating and its distinctiveness is time independent, it represents a meaningful integration of its total environment. It is on this basis that the climax vegetation is useful in the nomenclature of habitat types.

The habitat type classification provides a permanent and ecologically based system of land stratification in terms of vegetational potential (Daubenmire 1976). As the habitat type is the basic unit in classifying land units or sites based on their biotic potential, it emphasizes similarities and differences in ecosystems that carry implications for a variety of land management objectives (Daubenmire 1984). Some of the practical implications of habitat type classification are in predicting range and wildlife forage production and wildlife habitat values, timber production, species selection for regeneration methods, growth rates of ponderosa pine (Rioux 1984), susceptibility of trees to insects and disease, depth of soil moisture penetration, potential for producing browse after fire, impacts of recreational uses on the plant communities, natural areas for preservation, downed woody fuels on the forest floor, and successional trends after disturbance (Arno et al. 1985; Arno and Pfister 1977; Daubenmire 1961, 1968b, 1972; Fischer 1981; Fischer and Clayton 1983; Hansen et al. 1985; Hoffman 1984; Layser 1974; Mueggler and Stewart 1980; Pfister 1986). Habitat types offer a basis of comparison and evaluation in designing and carrying out field experiments in ecology or applied natural resource disciplines.

Methods

This study was started in 1981 with a reconnaissance survey. All the roads and trails and many off-road areas were traveled, and attention was spread rather uniformly over the entire study region, searching for sites that showed least amounts of disturbance. In all, about 200 sites were evaluated on a reconnaissance basis. Some of the sites were visited during each growing season of the study to verify the effects of significant differences in precipitation from one year to the next.

At each site, the plants observed were listed and coverage of the more important species estimated. The topographic position of the site, its elevation, slope and

aspect, and the approximate texture of the surface soil also were noted. Any prominent geologic and/or physiographic features at each site also were recorded. Though the sites were selected subjectively, the choices were based on a recognition of dominant plants and the presence of various species to indicate grazing or no grazing influence. Knowledge of the vegetation within and near Theodore Roosevelt National Park plus reference to studies of others in nearby areas were useful in selecting sites. In all cases, vegetation considered to exhibit the least amount of disturbance, and climax or near-climax, was sought. Based on the reconnaissance data, stands were tentatively grouped into habitat types.

During the field seasons of 1982, 1983, and 1984, 169 stands were intensively sampled. Some were taken from the list of reconnaissance sites; others were located during the time of intensive sampling. The number of plots sampled to describe each habitat type was based on the variability in coverage, frequency, and composition of vegetation. Habitat types with the greatest variability were sampled more often than those with less variability.

Somewhat different sampling techniques were used for forest and steppe or shrub-steppe vegetation. For forest vegetation, a rectangular plot 49.2 x 82.0 feet (15 x 25 m) was laid out with the long axis parallel to the contour of a slope to maximize the chance of remaining within the same soil type. The sample plots included the largest trees of the stand, provided the trees were not located near trails, ecotones, or other disturbances. Thus, the undergrowth vegetation and soil were most representative of the oldest part of the stand. Within each 4,036–square foot (375–m^2) main plot, all trees taller than 3.28 feet (1 m) were measured at breast height and recorded by 3.28–foot (1–dm) diameter classes. All trees less than 3.28 feet (1 m) tall throughout the plot also were tallied. In calculating tree basal areas, the midpoints of the diameter classes were tallied. Because the largest trees were included in the plots, the basal areas calculated were higher than would be expected for the average stand. The technique was used consistently, however, throughout the study, so the results were comparable from one stand to another. In determining basal area of *Juniperus scopulorum*, only the main stems were measured.

Each main plot was subdivided into three 16.4– x 82.0–foot (5– x 25–m) subplots. Canopy coverages for each shrub, forb, and graminoid undergrowth species were estimated within fifty 7.9– x 19.7–inch (2– x 5–dm) microplots placed at 3.28–foot (1–m) intervals along the inner sides of the central subplot. Canopy coverage for each species was recorded in one of six coverage classes: 1 = 0–5%, 2 = 6–25%, 3 = 26–50%, 4 = 51–75%, 5 = 76–95%, 6 = 96–100% (Daubenmire 1959). Mosses and lichens were combined for coverage estimates. Plant species in the main plot that did not occur in any of the fifty microplots also were noted. Increment cores of at least two of the largest trees present were sampled in each plot to provide estimates of the age of the stand.

Stands of steppe or shrub-steppe vegetation were sampled along a 164–foot (50–m) line transect that followed the contour of the hill (Daubenmire 1970). The sampling transect was placed within the least disturbed and most mature part of each stand. Here the fifty microplots were placed on alternate sides of the line. To calculate coverage and frequency values, methodology described by Daubenmire (1959) was used.

Finally, 25 soil cores representing the upper decimeter of the mineral soil were collected from each stand. These samples were composited and air-dried in the field.

In the laboratory, the dried soil samples were first passed through a 0.01–inch (2–mm) sieve. A modified Bouyoucos method (Moodie and Koehler 1975) was used to determine soil texture, and Hach Chemical procedures to determine pH (using a plastic-body electrode on the saturated soil paste), exchangeable Ca and Mg (EDTA titration method), K and P (bicarbonate method of extraction, a modification of the Olsen method), pH lime requirement (Ohio SMP method), cation exchange capacity and base saturation (addition method), and organic matter content (dichromate method).

Vegetation data were listed in association tables that grouped the stands within relatively distinct habitat types. Species among all layers of the vegetation were considered in grouping of stands, with first consideration given to climax dominants. For example, stands dominated by *Artemisia tridentata* were not grouped with those dominated by *A. cana*, since each shrub occupies relatively distinct habitats in the study area. The undergrowth in these cases may be quite similar, but the split is made on the basis of the single dominant and abiotic considerations. In the case of *Artemisia tridentata/Agropyron spicatum* and *Artemisia tridentata/Agropyron smithii* habitat types, the separation was made on the basis of undergrowth vegetation and on abiotic factors. The procedure is used throughout in grouping and regrouping stands, and developing, on the basis of both vegetation data and abiotic factors, a list of habitat types for the study region. Results of this study are first approximations in the sense that all vegetation data can be split more finely and result in more habitat types. However, based on data and knowledge of the region, it appears that the habitat types delimited and described will cover at least 85% of the landscape bearing vegetation in the study region (Daubenmire 1952, 1970; Daubenmire and Daubenmire 1968; Mueller-Dombois and Ellenberg 1974).

The following information is documented in the appendix tables: (1) tree population data (table A–1, appendix 1); (2) coverage and frequency data, location and number of stands sampled for each habitat type and community type (tables A–2 through A–25, appendix 2); and (3) soil analysis data for each habitat type and community type (table A–26, appendix 3).

Nomenclature for plants sampled in this study follows Van Bruggen (1976) and Barkley (1977). Although plants were collected at various times during the growing season and attempts were made to identify all specimens to species, there still were some difficulties related to the lack of clear taxonomic differences among certain species. Voucher specimens collected in the study were deposited in the herbarium at the University of South Dakota.

Steppe Habitat Types

Stipa comata/Carex filifolia

This habitat type, which occurs on nearly level plateaus, isolated buttes, and gentle slopes that appear to be relatively free from excessive erosion (fig. 5), is restricted to the eastern and central portion of the study region. In the 18 stands sampled, 90 species were recorded (table A–2). *Stipa comata, Carex filifolia, Agropyron smithii, Bouteloua gracilis, Artemisia frigida,* and *Koeleria pyramidata* provide the greatest coverage. Three unions usually are present in this association. *S. comata* forms the dominant union. Beneath the *S. comata* union is the *Agropyron smithii* union, which includes *K. pyramidata, Artemisia dracunculus, A. ludoviciana,* and *Lygodesmia juncea.* The lowest growing union of this association is dominated by *C. filifolia,* with a mean coverage of 53.9%. Other important species of this union are *B. gracilis, A. frigida, Gaura coccinea, Carex eleocharis,* and *Sphaeralcea coccinea.*

In the 18 stands sampled, 17 species had constancies of 50% or higher. Constancy and mean coverage percentages of major species are as follows:

Species	Constancy (%)	Mean coverage (%)
Stipa comata	100	76.4
Carex filifolia	100	53.9
Bouteloua gracilis	100	6.7
Agropyron smithii	94	10.2
Artemisia frigida	94	5.0
Gaura coccinea	83	0.4
Sphaeralcea coccinea	83	0.9
Koeleria pyramidata	78	4.3
Carex eleocharis	78	2.5
Lygodesmia juncea	78	0.6
Artemisia dracunculus	67	1.7

Figure 5.—Well-developed stand of the *Stipa comata/Carex filifolia* habitat type in the Ashland District, southeastern Montana. The meter stick used for scale in this and subsequent figures is in decimeter segments.

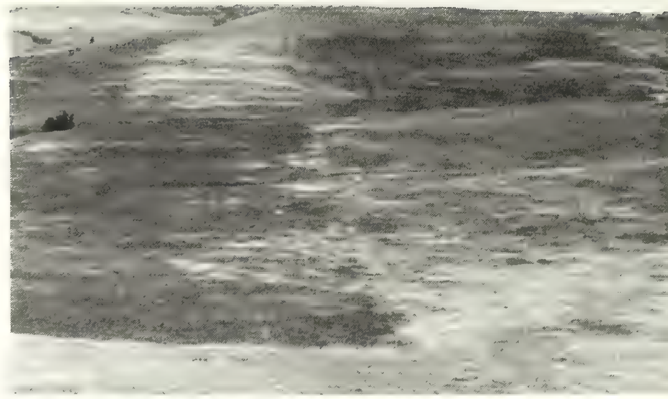

Figure 6.—Seral stands of *Agropyron cristatum* in the Grand River District, Custer National Forest, that are successional to the *Stipa comata/Carex filifolia* habitat type.

Compared to other steppe habitat types, forbs are relatively important but graminoids provide the greatest coverage. The mean graminoid coverage for the *S. comata/C. filifolia* habitat type is exceeded only by that of the *Calamovilfa longifolia/Carex heliophila* habitat type (table 1).

Soil textures range from loams to loamy sands. The high sand content of soils of *S. comata*-dominated vegetation corresponds to findings of others (Coupland 1961, Daubenmire 1970, Dix 1960, Hansen et al. 1984, Hanson 1935, Hanson and Whitman 1938, Lauenroth and Whitman 1977, Wright and Wright 1948). Sandy soils in this climate have a high infiltration rate, deep penetration of water, high moisture availability, but low moisture-holding capacity (table A–26).

Hansen et al. (1984) described the *S. comata/C. filifolia* plant association in Theodore Roosevelt National Park of western North Dakota, where it is considered to be a climatic climax. Much of the region once was planted with *Agropyron cristatum*, but signs of succession to the *S. comata/C. filifolia* plant association are evident in numerous locations (fig. 6). Mueggler and Stewart (1980) described an *Agropyron smithii* phase of a *S. comata/Bouteloua gracilis* habitat type in southwestern Montana that appears to be similar to the *S. comata/C. filifolia* habitat type. Hanson and Whitman (1938) described a community in western North Dakota dominated by *B. gracilis, S. comata,* and *C. filifolia*, and they suggested this community closely reflected the macroclimate of the region. Coupland (1950, 1961) described a *S. comata/B. gracilis* community of western Canada where *C. filifolia* is important and *S. comata* is a "productive" species. Coupland reported *C. filifolia* increases in abundance south from Canada; with grazing, *B. gracilis* becomes a dominant species. Data from the present study tend to confirm this. Following disturbance, stands show an increase in *Artemisia frigida, A. dracunculus, A. ludoviciana,* and an invasion of *Bromus japonicus.* With increased disturbance, *B. gracilis, Festuca octoflora,* and *Artemisia cana* may increase dramatically. Following severe disturbance, *Opuntia polyacantha* and *O. fragilis* may dominate the community.

Table 1.—Sums of mean coverages (percent) of shrubs, graminoids, and forbs in the habitat types of the Custer National Forest.

Habitat type	Mean coverage		
	Shrubs	Graminoids	Forbs
Steppe			
Stipa comata/Carex filifolia	5.1	162.5	17.2
Stipa comata/Carex heliophila	2.2	140.9	28.7
Festuca idahoensis/Carex heliophila	1.3	115.6	10.0
Agropyron smithii/Carex filifolia	1.3	137.2	14.8
Andropogon scoparius/Carex filifolia	1.3	112.6	9.5
Calamovilfa longifolia/Carex heliophila	0.3	181.8	6.0
Agropyron spicatum/Bouteloua curtipendula	4.0	79.0	7.7
Agropyron spicatum/Carex filifolia	5.0	105.5	23.0
Shrub-Steppe			
Artemisia tridentata/Agropyron spicatum	24.8	60.8	4.4
Artemisia tridentata/Agropyron smithii	26.4	69.1	13.2
Artemisia cana/Agropyron smithii	35.2	120.9	5.2
Juniperus horizontalis/Carex heliophila	84.0	52.0	9.6
Rhus aromatica/Agropyron spicatum	31.9	57.4	4.5
Rhus aromatica/Festuca idahoensis	27.0	118.0	5.0
Rhus aromatica/Carex filifolia	30.5	93.5	4.3
Sarcobatus vermiculatus/Agropyron spicatum	38.5	17.7	0.3
Sarcobatus vermiculatus/Agropyron smithii	23.5	104.5	1.5
Woodland			
Juniperus scopulorum/Agropyron spicatum	2.5	35.3	5.3
Juniperus scopulorum/Oryzopsis micrantha	6.0	50.3	20.3
Fraxinus pennsylvanica/Prunus virginiana	78.9	74.6	33.4
Populus tremuloides/Berberis repens	65.3	63.8	15.3
Forest			
Pinus ponderosa/Agropyron spicatum	1.3	51.3	2.0
Pinus ponderosa/Festuca idahoensis	0.0	69.5	2.5
Pinus ponderosa/Carex heliophila	0.3	80.3	0.7
Pinus ponderosa/Juniperus communis	40.0	27.5	1.0
Pinus ponderosa/Prunus virginiana	88.4	43.8	11.2
Community types			
Symphoricarpos occidentalis	100.0	22.0	40.0
Shepherdia argentea	206.0	97.0	67.0

Stipa comata/Carex heliophila

This habitat type, which occupies upland plateaus or open parks surrounded by *Pinus ponderosa* (fig. 7), is widespread in the central and western portion of the study area. Along the eastern edge of its distribution, it occupies sites wetter than those of the *Stipa comata/Carex filifolia* habitat type. In the 10 stands sampled, 73 species were recorded (table A–3). *S. comata*, *C. heliophila*, *Artemisia ludoviciana*, *Agropyron smithii*, and *Koeleria pyramidata* provide the greatest coverage.

Figure 7.—*Stipa comata/Carex heliophila* habitat type surrounded by stands of *Pinus ponderosa*, Long Pines, Sioux District, Custer National Forest.

The *S. comata/C. filifolia* and *S. comata/C. heliophila* habitat types show similar physiognomies. The major differences in the vegetation are the presence of *C. heliophila* and considerably greater coverage of forbs in the latter. The *S. comata* union dominates both, and the *Agropyron smithii* union is well represented. The low-growing *C. heliophila* union has a mean coverage of 48.3%. Other members of this union are *Antennaria rosea*, *Aster ericoides*, *Rosa arkansana*, and *Petalostemon purpureus*. *Selaginella densa* grows in scattered, dense mats close to the soil surface. Its overall coverage is 16.3% and it is most abundant in the central portion of the study region. *S. densa* is rare outside this association.

In the 10 stands sampled, 24 species had constancies of 50% or higher. Constancy and mean coverage percentages of the major species are as follows:

Species	Constancy (%)	Mean coverage (%)
Stipa comata	100	61.5
Carex heliophila	100	48.3
Artemisia ludoviciana	100	6.1
Agropyron smithii	100	5.2
Koeleria pyramidata	100	5.1
Stipa viridula	90	5.4
Antennaria rosea	90	0.7
Gaura coccinea	90	0.2
Aster ericoides	80	1.7
Artemisia frigida	80	1.4
Rosa arkansana	70	0.6
Petalostemon purpureus	70	0.2

Owing to greater moisture in this habitat type, forbs provide almost twice the coverage as in the *S. comata/C. filifolia* plant association (table 1). Again, graminoids dominate this habitat type and provide the greatest coverage.

The *S. comata/C. heliophila* plant association is a climatic climax in the central and western portion of the study area. In typical stands, disturbance results in an increase in *Artemisia dracunculus, A. frigida, A. ludoviciana*, and an invasion of the alien species *Poa pratensis* and *Bromus japonicus.* With increased disturbance, *Artemisia cana*, and to a lesser degree *A. tridentata*, invade and eventually may dominate the community. These disturbed steppe sites can be distinguished from habitat types dominated by *A. cana* and *A. tridentata*. The *Artemisia cana/Agropyron smithii* habitat type occurs on alluvial deposits, and herbaceous species serve to distinguish the *Artemisia tridentata*-dominated habitat types.

Edaphic characteristics of the *S. comata/C. heliophila* and *S. comata/C. filifolia* habitat types are similar. Soil textures range from loams to loamy sands (table A–26).

There are few reports of *S. comata*-dominated communities having an abundance of *C. heliophila*. Hanson and Whitman (1938) described a community in western North Dakota dominated by *Bouteloua gracilis, S. comata*, and *C. filifolia* with limited amounts of *C. heliophila*. Larson and Whitman (1942) described a community dominated by *Agropyron smithii, S. comata*, and *Carex eleocharis* in the badlands of South Dakota where C. heliophila was more abundant on a protected mesa than on one periodically mowed and grazed. In Canada, Coupland (1961) described a *Stipa spartea* and *Agropyron dasystachyum* community in which *C. heliophila* was an important species. In western North Dakota, Redmann (1975) reported a *S. comata* community with an abundance of *C. heliophila*.

Festuca idahoensis/Carex heliophila

This habitat type, which occurs on upland plateaus or open parks that are surrounded by *Pinus ponderosa* (fig. 8), is restricted to the western portion of the study region. In the 8 stands sampled, 60 species were recorded (table A–4). The limited presence of *S. comata* and the constant occurrence and abundance of *Festuca idahoensis, C. heliophila, Koeleria pyramidata, A. ludoviciana, Aster ericoides*, and *Agropyron smithii* delineate this habitat type from other steppe habitat types.

Figure 8.—*Festuca idahoensis/Carex heliophila* habitat type on a gentle slope near Diamond Butte, Ashland District, southeastern Montana.

The physiognomy of the vegetation is similar to that of the *S. comata/C. heliophila* habitat type though the *F. idahoensis/C. heliophila*-dominated vegetation has less forb coverage, less leaf litter, and more exposed soil surface. The *F. idahoensis/C. heliophila* plant association also lacks the scattered dense mats of *Selaginella densa*. The *F. idahoensis* union is dominant, and its abundance and stature is indicative of this association. The *S. comata, Agropyron smithii, Artemisia frigida*, and *C. heliophila* unions also are represented. The *F. idahoensis/C. heliophila* plant association is climatic climax in the western portion of the study area.

In the 10 stands sampled, 22 species had constancies of 50% or higher. Constancy and mean coverage percentages of the major plants of this habitat type are as follows.

Species	Constancy (%)	Mean coverage (%)
Festuca idahoensis	100	75.3
Carex heliophila	100	25.5
Koeleria pyramidata	100	4.0
Artemisia ludoviciana	100	2.8
Aster ericoides	100	2.7
Agropyron smithii	100	2.6
Stipa comata	88	2.6
Rosa arkansana	75	0.8
Antennaria rosea	75	0.3
Artemisia frigida	75	0.3
Bouteloua gracilis	63	1.8
Gaura coccinea	63	0.1

Graminoids dominate this habitat type, and the summed forb and shrub coverage is less than that of the previous two habitat types (table 1). Soil textures of this habitat type range from loams to sandy loams. Other edaphic characteristics are shown in table A–26.

Others have described similar communities; Hurd (1961) described a *F. idahoensis/Lupinus sericeus* community in the Bighorn Mountains of north-central Wyoming where the undergrowth contained large

amounts of *Carex obtusata*. In the same area, Despain (1973) described a *F. idahoensis*-dominated community in which the major associates were *C. obtusata, Agoseris glauca*, and *Lupinus sericeus*. Mueggler and Stewart (1980) reported a *F. idahoensis/C. filifolia* habitat type generally confined to the higher elevations in southwestern Montana, and Wright and Wright (1948) identified a *F. idahoensis* community in south-central Montana.

Agropyron smithii/Carex filifolia

This habitat type occurs on nearly level upland depressions, gently sloping hillsides and on floodplains along the major streams. The *Agropyron smithii/Carex filifolia* habitat type is not widespread and is restricted to the eastern and central portions of the study region. In the 10 stands sampled, 64 species were recorded (table A–5). Nearly pure swards of *A. smithii* dominate undisturbed stands and *C. filifolia* and *Carex eleocharis* provide limited coverage. Constancy and mean coverage percentages of the major plants of the 10 stands sampled are as follows:

Species	Constancy (%)	Mean coverage (%)
Agropyron smithii	100	85.1
Bouteloua gracilis	50	4.1
Stipa viridula	50	3.4
Stipa comata	50	1.7
Carex filifolia	40	19.2
Carex eleocharis	40	5.4

In the present study, only 4 of the 64 species have constancies of 50% or more. The number of species per stand ranges from 3 to 29; the average was 12 species per stand.

Most stands of this habitat type are easily accessible to livestock, and because *A. smithii* is very palatable, many stands have numerous "weedy" species. Two stands sampled are relatively undisturbed. Stand 73, located on a floodplain of the South Fork of the Grand River in the Grand River District, is within a study exclosure established in 1961. Inside the exclosure, *A. smithii* has produced a luxuriant sward with a coverage of 98% (fig. 9). Other major species are *C. eleocharis* and *C. filifolia*. Outside the exclosure, the broad floodplain is severely overgrazed and *Bouteloua gracilis, Buchloe dactyloides*, and *Festuca octoflora* dominate the vegetation (fig. 10). Stand 8, also in an exclosure in the Grand River District, is on a gently sloping hillside. *A. smithii* is dominant with a coverage of 92%. *C. filifolia* and *Stipa viridula* have coverages of 70% and 12%, respectively. In this habitat type, graminoids again provide the greatest coverage (table 1).

Differences in abundances of *A. smithii* versus *S. comata* readily distinguish the *A. smithii/C. filifolia* and the *S. comata*-dominated vegetation. The *A. smithii/C. filifolia* plant association is an edaphic climax.

Soils of this habitat type range from clay loams to loams (table A–26). The clay content ranges from 12.0% to 38.6%. Fine-textured soils in this region generally have poor water balance, which explains, in part, the limited species diversity in undisturbed stands of this habitat type. *A. smithii*, however, thrives on heavy soils in the region (Weaver and Albertson 1956).

Figure 9.—*Agropyron smithii/Carex filifolia* habitat type in the Grand River District, Custer National Forest. This stand (73) has been protected from grazing since 1961.

Figure 10.—Heavy grazing outside of exclosure protecting stand 73 has eliminated nearly all of the *Agropyron smithii*. Stand is dominated by *Bouteloua gracilis, Buchloe dactyloides*, and *Festuca octoflora*.

Hansen et al. (1984) described this habitat type in Theodore Roosevelt National Park of western North Dakota, where the vegetation is an edaphic climax. Hanson and Whitman (1938) described a plant community in western North Dakota dominated by *A. smithii, Bouteloua gracilis*, and *C. filifolia* occurring on gradual slopes of fine-textured materials. Quinnild and Cosby (1958) found vegetation of mesa tops in western North Dakota dominated by *A. smithii, A. dasystachyum, S. comata, Bouteloua gracilis*, and *Artemisia frigida*. Larson and Whitman (1942) also reported an *Agropyron smithii*-dominated community on mesas in the badlands of South Dakota. Their results indicated that complete protection maintains a vegetation dominated by *A. smithii, C. filifolia*, and *C. eleocharis*, while combined mowing and grazing produces vegetation dominated by *B. gracilis*. Coupland (1950, 1961) described a community

in Canada dominated by *A. smithii* and *A. dasystachyum* occurring on fine-textured soils. Observations overall have been consistent in documenting the affinity of *A. smithii* for fine-textured soils.

Andropogon scoparius/Carex filifolia

This habitat type is restricted to the shoulders and slopes of buttes and hills (fig. 11). *Andropogon scoparius/Carex filifolia* and *Fraxinus pennsylvanica/Prunus virginiana* are the only habitat types that occur throughout the study area. In the 16 stands sampled in this habitat type, 111 species were recorded (table A–6). With a mean coverage of 75.7%, *A. scoparius* dominates and characterizes the vegetation. *Bouteloua curtipendula, Echinacea angustifolia, Oxytropis lambertii, Psoralea argophylla,* and *Liatris punctata* are other important species in this union. The *C. filifolia, Agropyron smithii,* and *C. heliophila* unions also are represented. Dense layers of litter and duff usually cover the soil surface.

Twenty species had constancies of 50% or higher. Constancy and mean coverage percentages of major species are as follows:

Species	Constancy (%)	Mean coverage (%)
Andropogon scoparius	100	75.7
Carex filifolia	100	28.0
Koeleria pyramidata	88	1.3
Petalostemon purpureus	88	1.1
Artemisia frigida	88	0.4
Echinacea angustifolia	81	1.8
Aster ericoides	81	0.4
Oxytropis lambertii	75	0.6
Psoralea argophylla	75	0.4
Rosa arkansana	69	0.3
Liatris punctata	63	0.2
Bouteloua curtipendula	56	5.3
Lygodesmia juncea	50	0.2

Though forbs provide limited coverage (table 1), the numerous species add considerable diversity to the vegetation. Though forbs and shrubs are well represented, both growth forms provide less coverage than in the *Stipa comata/Carex filifolia* and *S. comata/C. heliophila* habitat types.

Figure 11.—***Andropogon scoparius/Carex filifolia*** **habitat type scattered across hillsides on the Grand River District southwest of Hettinger, North Dakota.**

Figure 12.—***Calamovilfa longifolia/Carex heliophila*** **habitat type, southeast of Shadehill Reservoir, Grand River District, is restricted to sandy soils. Abrupt ecotones are typical where this habitat type adjoins another habitat type.**

Soils range from loams to loamy sands (table A–26). Because of the topographic position and the generally coarse-textured soils, the *A. scoparius/ C. filifolia* habitat type is a topoedaphic climax.

Hansen et al. (1984) identified this habitat type in Theodore Roosevelt National Park of western North Dakota where the vegetation is a topoedaphic climax. Hanson and Whitman (1938) reported an *A. scoparius* community occurring on north-facing slopes and in open areas where snow accumulates. Redmann (1975) described a community on north-facing slopes dominated by *A. scoparius* in which *Rosa arkansana* and *Helianthus rigidus* also were important species. Jorgenson (1979) described a *Muhlenbergia cuspidata/A. scoparius* habitat type on loams and stoney loam soils derived from red shale in the Yellow Water Triangle, Montana.

Calamovilfa longifolia/Carex heliophila

This habitat type occurs in the eastern and central portions of the study region, and stands are limited in both size and extent. Typically, the stands are irregular in size and are scattered across the gently rolling landscape (fig. 12). Undisturbed vegetation in the *Calamovilfa longifolia/Carex heliophila* habitat type consists of these two graminoids and very little else, although widely scattered individuals of *Bouteloua gracilis, Koeleria pyramidata,* and *Artemisia ludoviciana* may be present. *Calamovilfa longifolia* forms the dominant union, with its abundance and stature indicative of this association. The *Carex heliophila, Agropyron smithii,* and *C. filifolia* unions also are represented. Four stands were sampled with a total of only 33 species (table A–7), although 17 had constancies of 50% or higher.

Constancy and mean coverage percentages of major species in this association are as follows:

Species	Constancy (%)	Mean coverage (%)
Calamovilfa longifolia	100	94.6
Carex heliophila	100	84.1
Bouteloua gracilis	100	1.3
Koeleria pyramidata	100	0.3
Artemisia ludoviciana	75	2.1
Lygodesmia juncea	75	0.7
Poa pratensis	75	0.5
Artemisia frigida	75	0.3

In the *Calamovilfa longifolia/Carex heliophila* plant association, graminoids have the highest and forbs and shrubs the lowest mean coverages of all the steppe associations of this study (table 1).

Soils range from sandy loams to sands (table A–26). Sandy soils permit moderate to rapid water infiltration with little or no runoff, and deep-rooted mesophytic grasses like *Calamovilfa longifolia* more readily survive on sandy soils in this semiarid to arid environment. The *Calamovilfa longifolia/Carex heliophila* habitat type is an edaphic climax in the study region.

Hanson and Whitman (1938) identified a *Calamovilfa longifolia* community on sandy ridges and hills in western North Dakota. *Carex heliophila* also was an important species of this community. In western Canada, Coupland (1961) described stands of *Calamovilfa longifolia* that also occupied sandy soils.

Agropyron spicatum/Bouteloua curtipendula

Only three stands in this habitat type were sampled, but numerous others were observed. The *Agropyron spicatum/Bouteloua curtipendula* habitat type is restricted to the western portion of the study region, occurring on foothills and hillsides along major drainages (fig. 13). The slopes of the stands range from 25% to 55%. The plant association is dominated by *A. spicatum*; members of the *Andropogon scoparius* union also are present. The sites are dominated by the caespitose grass *Agropyron spicatum* and very little else, though widely scattered individuals of *B. curtipendula* are present. The vegetation

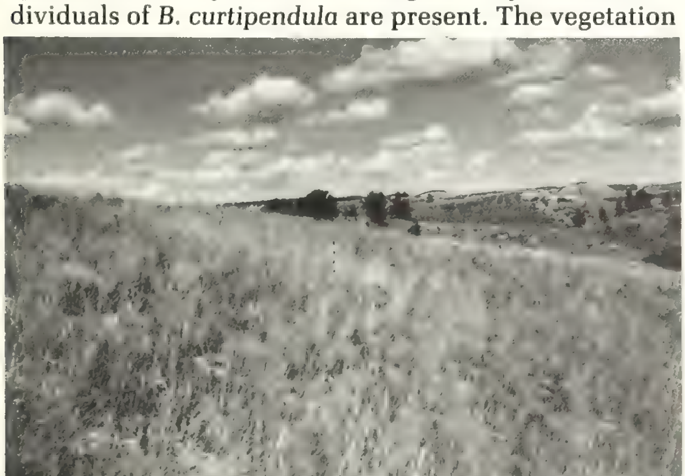

Figure 13.—*Agropyron spicatum/Bouteloua curtipendula* habitat type on a hillside in the Ashland District, southeastern Montana.

Figure 14.—*Agropyron spicatum/Carex filifolia* habitat type dominates an upland plateau on the Ashland District, Custer National Forest.

is similar to that of the *Rhus aromatica/Agropyron spicatum* habitat type, described below, except for the absence of *R. aromatica*. The *A. smithii* and *Carex filifolia* unions also are represented in the undergrowth. The soil surface usually contains large amounts of irregularly shaped, reddish, iron oxide porcelainite shale called scoria.

In the three stands sampled, 52 species were recorded (table A–8); 22 species had constancies of 50% or higher. Constancy and mean coverage percentages of major species are as follows:

Species	Constancy (%)	Mean coverage (%)
Agropyron spicatum	100	49.6
Bouteloua curtipendula	100	9.5
Lygodesmia juncea	100	0.5
Agropyron smithii	67	8.6
Andropogon scoparius	67	5.8
Carex filifolia	67	1.4
Echinacea angustifolia	67	0.8
Psoralea argophylla	67	0.3

Of all the steppe plant associations in this study, the *Agropyron spicatum/Bouteloua curtipendula* habitat type had the lowest graminoid coverage and the lowest total coverage (table 1).

Because of topographic and edaphic characteristics, the *A. spicatum/B. curtipendula* plant association is a topoedaphic climax. The soils are loams (table A–26).

Mueggler and Stewart (1980) described three *A. spicatum*-dominated habitat types in western Montana. The *A. spicatum/Bouteloua gracilis* habitat type, occurring east of the Continental Divide on the more southerly exposures, with slopes up to 35%, appears to be similar to the *A. spicatum/B. curtipendula* habitat type of this study.

Agropyron spicatum/Carex filifolia

Only two stands of this habitat type were sampled; its distribution is limited and it occurs only in the western portion of the study area. The sites occupy nearly level, relatively xeric, upland plateaus or buttes (fig. 14). The

vegetation is dominated by *Agropyron spicatum*, with limited coverage of *Carex filifolia*. The *A. spicatum*, *C. filifolia*, *A. smithii*, and *Stipa comata* unions are represented. Following disturbance, *Bromus japonicus* becomes established, and *Ambrosia psilostachya* and *Artemisia frigida* increase in abundance. In the two stands sampled, 39 species were recorded (table A–8). Constancy and mean coverage percentages of the major plants in the two stands are as follows:

Species	Constancy (%)	Mean coverage (%)
Agropyron spicatum	100	58.1
Carex filifolia	100	14.6
Bromus japonicus	100	12.3
Ambrosia psilostachya	100	8.0
Koeleria pyramidata	100	7.1
Stipa comata	100	4.1
Artemisia frigida	100	4.1
Bouteloua gracilis	100	0.7
Agropyron smithii	100	0.6
Carex eleocharis	100	0.2
Gaura coccinea	100	0.2

Graminoids provide the greatest cover, though forbs are relatively important (table 1).

Although species lists of the *Agropyron spicatum/Carex filifolia* and *A. spicatum/Bouteloua curtipendula* habitat types are similar, the difference in topographic positions and the absence of *B. curtipendula* in the former warrants separating these two habitat types. Soil textures for the two stands sampled are silt loams (table A–26). The *A. spicatum/C. filifolia* plant association is considered to be an edaphic climax.

Mueggler and Stewart (1980) described a *Liatris punctata* phase of an *Agropyron spicatum/Bouteloua gracilis* habitat type east of the Continental Divide in Montana. The phase is characterized by the presence of *L. punctata*, *C. filifolia*, and *Calamagrostis montanensis*, and it is similar to the *A. spicatum/Carex filifolia* habitat type of this study. In the Bighorn Mountains of north-central Wyoming, Despain (1973) described an *A. spicatum* community occurring on the western flank at lower elevations. Conspicuous species include *C. filifolia*, *Koeleria pyramidata*, and *Phlox hoodii*.

Shrub-Steppe Habitat Types

Artemisia tridentata/Agropyron spicatum

This habitat type occupies steep-to-moderate south-facing talus-covered slopes (fig. 15) to gentle footslopes along the major drainages in the western portion of the study region. Some stands are quite extensive and cover entire hillsides. In the five stands sampled, 53 species occurred (table A–9).

Relatively undisturbed stands of this habitat type are distinguished by the dominant shrub *Artemisia tridentata* and by *Agropyron spicatum* as the principal grass. *Koeleria pyramidata*, *Stipa viridula*, and *Agropyron smithii* may be present, but their summed coverages

Figure 15.—*Artemisia tridentata/Agropyron spicatum* habitat type on a moderate south-facing slope northeast of Birney, Montana, Ashland District. Dominance of *A. spicatum* in the undergrowth is evident.

never equal that of *A. spicatum*. The vegetation consists of two well-defined layers. *Artemisia tridentata*, the only member of its union, averages 1.0 to 1.64 feet (3 to 5 dm) in height and dominates the upper layer. *Agropyron spicatum* dominates the lower layer along with other caespitose perennial grasses. *A. smithii* and *Carex filifolia* unions also may be represented. Soil surfaces usually are exposed in this habitat type.

In the five stands sampled, 16 species had constancies of 50% or higher. Constancy and mean coverage percentages of major species are as follows:

Species	Constancy (%)	Mean coverage (%)
Artemisia tridentata	100	21.2
Agropyron spicatum	100	40.1
Sphaeralcea coccinea	100	0.2
Koeleria pyramidata	80	5.0
Agropyron smithii	80	3.3
Artemisia frigida	80	0.4
Bouteloua gracilis	60	0.4

Shrubs and graminoids are most conspicuous in the *A. tridentata/A. spicatum* habitat type, and forbs are relatively sparse (table 1).

Severely disturbed stands of the *Artemisia tridentata/Agropyron spicatum* and the *Stipa comata/Carex heliophila* habitat types are similar. Both show increased amounts of *Artemisia frigida*, *Gutierrezia sarothrae*, *Achillea millefolium*, *Camelina microcarpa*, *Poa pratensis*, and *Bromus japonicus*. However, topographic position and the abundance of *Artemisia tridentata* distinguish these two habitat types.

The *Artemisia tridentata/Agropyron spicatum* plant association is a topographic climax. Soil textures of the five stands include loams, sandy clay loam, and sandy loam (table A–26).

Daubenmire (1970) described an *Artemisia tridentata/Agropyron spicatum* habitat type in the steppe of eastern Washington, occurring mostly on loams or stony loams. Daubenmire classified the vegetation as climatic climax and indicated it probably is the most extensive element in the steppe mosaic of eastern Washington. In western

Montana, Mueggler and Stewart (1980) identified an *Artemisia tridentata/Agropyron spicatum* habitat type that occurred on a variety of exposures, slopes, and soils. The vegetation differs from that in Washington in having the low shrubs *Artemisia frigida, Gutierrezia sarothrae,* and *Opuntia polyacantha,* and the grasses *Koeleria pyramidata* and *Bouteloua gracilis*. The forb components also differed. The *Artemisia tridentata/Agropyron spicatum* habitat type of this study is similar to that of western Montana. Mackie (1970), in north-central Montana, and Hironaka et al. (1983), in southern Idaho, described *Artemisia tridentata/Agropyron spicatum* habitat types which appear to be similar to that of western Montana and the present study. In eastern Montana, Brown (1971) described two communities restricted to talus slopes of southwest exposure dominated by *Artemisia tridentata* and *Agropyron spicatum*. In the Bighorn Mountains of Wyoming, Despain (1973) described a similar community occurring at lower elevations.

The *Artemisia tridentata/Agropyron spicatum* plant association described by Daubenmire (1970) for Washington is distinct from all others with the same name described for Montana and Idaho. These latter plant associations have species of the mid-continental steppe, as indicated above, which are lacking in this habitat type in Washington.

Artemisia tridentata/Agropyron smithii

This habitat type occurs on gently rolling upland topography in the western portion of the study region, with a limited number of stands in the central portion. Many of the stands are extensive and cover large areas of the landscape (fig. 16). Because of their position, the stands are easily accessible to livestock, and most sites show various degrees of disturbance. In the seven stands sampled, 50 species were recorded (table A–10).

Artemisia tridentata dominates the shrub layer and *Agropyron smithii* dominates the herbaceous layer in relatively undisturbed stands. *Koeleria pyramidata, Poa canbyi,* and *Stipa viridula* are additional important grasses of this association. The *Artemisia tridentata, Agropyron smithii,* and the *Carex filifolia* unions are represented. Physiognomically, the vegetation is identical to that of the *Artemisia tridentata/Agropyron spicatum* association; the herbaceous unions distinguish the two associations.

In the seven stands sampled, only 13 species had constancies of 50% or higher. Constancy and mean coverage percentages of major species are as follows:

Species	Constancy (%)	Mean coverage (%)
Artemisia tridentata	100	23.7
Agropyron smithii	100	39.2
Koeleria pyramidata	86	8.9
Poa canbyi	86	5.9
Bouteloua gracilis	86	2.4
Stipa viridula	71	6.7
Sphaeralcea coccinea	71	0.2
Artemisia frigida	57	0.5

Figure 16.—Ungrazed stand in the *Artemisia tridentata/Agropyron smithii* habitat type west of Diamond Butte, Ashland District, southeastern Montana. Note dominance of graminoids in the undergrowth.

Typically, the stands are open and much soil surface is exposed. Grazing reduces the coverage of major grass species, possibly confining them to areas directly beneath the shrub canopies. After severe disturbance, *Gutierrezia sarothrae, Bouteloua gracilis, Bromus japonicus, Achillea millefolium, Camelina microcarpa, Opuntia fragilis,* and *O. polyacantha* increase and palatable species decrease in abundance. Shrubs and graminoids are the most conspicuous growth forms in this habitat type, and forb coverages are the highest among the shrub-steppe habitat types (table 1).

Soil textures for the seven stands are loams and sandy clay loam (table A–26). The *Artemisia tridentata/Agropyron smithii* habitat type is considered to be an edaphic climax. *Artemisia tridentata* and *Agropyron smithii* also occur on heavy soils elsewhere (Tisdale and Hironaka 1981, Weaver and Albertson 1956).

In Theodore Roosevelt National Park of western North Dakota, this plant association is a topoedaphic climax on narrow benches or terraces above the valley floor of the Little Missouri River and its principal tributaries (Hansen et al. 1984). In north-central Montana, an *Artemisia tridentata/Agropyron smithii* plant association occurs as an edaphic climax on "shallow, gravelly, or claypan surface soils" (Mackie 1970). Other studies indicate broad vegetational similarities among *Artemisia tridentata*-dominated vegetation in western North Dakota (Hazlett and Hoffman 1975, Whitman and Hanson 1939).

Artemisia cana/Agropyron smithii

This habitat type occupies narrow floodplains and coalescing alluvial fans in valleys 98 to 820 feet (30 to 250 m) wide throughout the central and western portions of the study region (fig. 17). The *Artemisia cana/Agropyron smithii* habitat type is not extensive, but it is locally abundant. The stands are readily accessible to livestock and most show signs of disturbance. In the six stands sampled, 43 species were recorded (table A–11).

Artemisia cana dominates the shrub layer and *Agropyron smithii* dominates the herbaceous layer. *Stipa*

viridula also is important in undisturbed stands. *Artemisia cana* and *Agropyron smithii* unions are represented in this association. Following disturbance, *Poa pratensis, Bromus japonicus, Bouteloua gracilis, Achillea millefolium, Melilotus officinalis*, and *Taraxacum officinale* increase greatly, while *Agropyron smithii* and *S. viridula* decrease most noticeably. Palatable species still present in severely overgrazed stands are restricted to areas beneath the canopies of *Artemisia cana*.

In the six stands sampled, only 12 species had constancies of 50% or higher. Constancy and mean coverage percentages of major species are as follows:

Species	Constancy (%)	Mean coverage (%)
Artemisia cana	100	34.2
Agropyron smithii	100	72.0
Poa pratensis	100	20.7
Stipa viridula	100	5.4
Koeleria pyramidata	50	2.1

Shrubs and graminoids are the most conspicuous growth forms in this habitat type; forbs are sparse (table 1).

Though the sites may be contiguous, the *Artemisia cana/Agropyron smithii* habitat type is wetter than the *Artemisia tridentata/Agropyron smithii* habitat type, which may account for the greater coverage of graminoids in the former. On favorable sites, *Artemisia cana* often grows to 5 feet (1.5 m).

Soil textures for the six stands are loams (table A–26). Others have reported *Artemisia cana* occurring on medium-textured soils (Beetle and Johnson 1982, Hazlett and Hoffman 1975, Tisdale and Hironaka 1981). The *Artemisia cana/Agropyron smithii* plant association is considered to be an edaphic climax in the study region.

In Theodore Roosevelt National Park of western North Dakota, this habitat type also is an edaphic climax on floodplains and river terraces adjacent to the Little Missouri River and its tributaries (Hansen et al. 1984). Mueggler and Stewart (1980) described *Artemisia cana*-dominated communities occurring on deep, loamy, alluvial soils along some mountain streams at elevations usually over 5,994 feet (1,827 m) in southwestern Montana. The dominant grass was *Festuca idahoensis*. In southern Idaho, Hironaka et al. (1983) described two minor *A. cana*-dominated habitat types, the *A. cana/F. idahoensis* habitat type along stream courses or in meadows where soil moisture is high, and the *A. cana/Muhlenbergia richardsonis* habitat type on poorly drained soils. The latter is more abundant farther west in Oregon and California.

Figure 17.—*Artemisia cana/Agropyron smithii* habitat type, Long Pines, Sioux District, Custer National Forest. This habitat type usually occurs on deep, loamy, alluvial soils.

Figure 18.—*Juniperus horizontalis/Carex heliophila* habitat type on a steep north-facing hillside, Slim Buttes, Sioux District, Custer National Forest.

Juniperus horizontalis/Carex heliophila

This habitat type occurs on steep north-facing slopes in the central portion of the study region. In the Slim Buttes and the Long Pines, many of the stands are quite extensive and cover entire hillsides (fig. 18). The *Juniperus horizontalis/Carex heliophila* habitat type is distinguished by the dominance of *J. horizontalis*, with a mean coverage of 81.9%, and the presence of *C. heliophila*, with a mean coverage of 20.4%. In the seven stands sampled, 67 species were recorded (table A–12).

The *J. horizontalis/C. heliophila* habitat type has a complex physiognomy. Members of the *J. horizontalis* union include the tall [up to 1.3 feet (4 dm)] *Agropyron dasystachyum* and the somewhat shorter *Thermopsis rhombifolia, Koeleria pyramidata*, and *Petalostemon purpureus*. *J. horizontalis*, which dominates the vegetation, is short-statured and hardly overtops members of the *C. heliophila* union. The tallest species is *Andropogon scoparius*, which has limited coverage but is conspicuous because of its height. The *Agropyron smithii* and *Carex filifolia* unions also are represented.

In the seven stands sampled, 32 species had constancies of 50% or higher. Constancy and mean coverage percentages of major species in this habitat type are as follows:

Species	Constancy (%)	Mean coverage (%)
Juniperus horizontalis	100	81.9
Carex heliophila	100	20.4
Andropogon scoparius	100	13.5
Carex filifolia	100	4.9
Thermopsis rhombifolia	100	2.4
Koeleria pyramidata	100	1.3

Campanula rotundifolia	100	0.8
Artemisia frigida	100	0.5
Agropyron dasystachyum	86	5.8
Anemone patens	86	1.4
Petalostemon purpureus	86	1.0
Symphoricarpos occidentalis	86	0.9
Galium boreale	86	0.7

Stands of the *Juniperus horizontalis/Carex heliophila* habitat type may be contiguous with those of *Andropogon scoparius/Carex filifolia*; other stands contact *A. scoparius*-dominated communities in which *C. heliophila* is abundant. Examples are stands 46 and 48 (table A–12); these are late-seral stages of the *J. horizontalis/C. heliophila* habitat type in which *A. scoparius* is abundant. As the stands mature, *J. horizontalis* forms a dense mat, *C. heliophila* increases, and *A. scoparius* decreases in importance.

Of the shrub-dominated habitat types, *J. horizontalis/C. heliophila* and *Sarcobatus vermiculatus/Agropyron spicatum* are the only ones in which the mean coverage of the shrubs exceeds that of the graminoids (table 1).

Soil textures of the seven stands are all sandy loams (table A–26). Ranges of sand content and organic matter content are 57.5% to 72.4% and 4.30% to 5.46%, respectively. On the basis of topographic and edaphic factors, the *J. horizontalis/C. heliophila* plant association is considered a topoedaphic climax.

In western North Dakota, the *J. horizontalis/Andropogon scoparius* plant association occurs as a topoedaphic climax where soil textures range from clay loam to loam (Hansen et al. 1984). Except for the abundance of *A. scoparius*, the presence of *Potentilla fruticosa*, and the absence of *C. heliophila* and *Agropyron dasystachyum*, the *J. horizontalis/Andropogon scoparius* and *J. horizontalis/C. heliophila* habitat types are similar. *J. horizontalis*-dominated vegetation also occurs in Alberta and in western North Dakota (Coupland 1961, Quinnild and Cosby 1958, Redmann 1975, Whitman and Hanson 1939).

Rhus aromatica/Agropyron spicatum

This habitat type occurs as patches or strips on convex shoulders and steep, xeric, south-facing hillsides (fig. 19). In the five stands sampled, the slopes exceeded 52%. Stands of the *Rhus aromatica/Agropyron spicatum* habitat type are limited in size and extent in the central portion but are more numerous in the western portion of the study area. The soils are rocky, and many sites have large amounts of reddish iron oxide porcelainite material. Ordinarily, considerable amounts of rock and mineral soil are exposed at the soil surface (table A–13). In the five stands sampled, only 47 species were recorded.

The shrub layer is dominated by *R. aromatica*, 1 to 2 feet (3 to 6 dm) tall, with 27% to 36% coverage. The herbaceous layer is dominated by *A. spicatum*, with limited amounts of *A. smithii* and *Bouteloua curtipendula*. The annual *Bromus tectorum* is infrequent. The more conspicuous forbs include *Sphaeralcea coccinea, Gaura coccinea, Ambrosia psilostachya*, and *Vicia americana*.

Figure 19.—*Rhus aromatica/Agropyron spicatum* habitat type on a steep south-facing hillside, Ashland District, southeastern Montana. Upslope stands in this habitat type adjoin either steppe- or *Pinus ponderosa*-dominated vegetation.

Except for the greater abundance of *R. aromatica*, the *R. aromatica/Agropyron spicatum* and *A. spicatum/Bouteloua curtipendula* associations are similar. The *R. aromatica, A. spicatum, A. smithii, Carex filifolia*, and *Andropogon scoparius* unions are all represented.

In the five stands sampled, only nine species had constancies of 50% or higher. Major species of this habitat type and their constancy and mean coverage percentages are as follows:

Species	Constancy (%)	Mean coverage (%)
Rhus aromatica	100	30.0
Agropyron spicatum	100	39.8
Agropyron smithii	100	5.0
Bouteloua curtipendula	80	7.5
Sphaeralcea coccinea	80	0.5
Gaura coccinea	80	0.1

The lower sums of coverages in stands of the *Rhus aromatica/Agropyron spicatum* and the *Artemisia tridentata*-dominated plant associations reflect the more xeric nature of these habitat types (table 1).

This habitat type occupies a rather intermediate topographic position such that upslope it contacts either steppe or *Pinus ponderosa*-dominated vegetation, and downslope it contacts either steppe or *Artemisia tridentata*-dominated vegetation.

Soil textures range from sandy in the central part to loamy with much porcelainite in the western part of the study region (table A–26). Because of topographic and edaphic characteristics, the vegetation of the *Rhus aromatica/Agropyron spicatum* habitat type is considered to be a topoedaphic climax.

Mueggler and Stewart (1980) described the *R. aromatica/A. spicatum* habitat type in south-central Montana, where it occurs on south- and west-facing sedimentary benchlands or terraces of low-elevation breaks along major tributaries of the Missouri River. Their stands are similar in both physiognomy and vegetation to the stands sampled in the present study. In the Ashland District, Brown (1971) identified a *R. aromatica/A. spicatum* com-

munity located on and immediately below ridgetops; these stands probably represent the *R. aromatica/A. spicatum* habitat type described here.

Rhus aromatica/Festuca idahoensis

This infrequent habitat type occurs primarily as patches or strips on shoulders and slopes of gently rolling hillsides in the western portion of the study region (fig. 20). Considerable rock and mineral soil are exposed on the soil surface. Although the *Rhus aromatica/Festuca idahoensis* habitat type is wetter than the *R. aromatica/Agropyron spicatum* habitat type, both share numerous species and both are topoedaphic climaxes. *A. spicatum* may be more abundant than *F. idahoensis* in the *R. aromatica/F. idahoensis* habitat type, but *Festuca* is not present in stands of *R. aromatica/A. spicatum* habitat type, and this is primarily the basis for separation. Other conspicuous graminoids include *Carex heliophila, Poa canbyi,* and the introduced annual *Bromus japonicus.* This habitat type is dominated by members of the *F. idahoensis, A. spicatum, A. smithii, C. heliophila,* and *Andropogon scoparius* unions. In the two stands sampled, only 26 species were recorded (table A–13).

Characteristic species with constancy and mean coverage percentages are as follows:

Species	Constancy (%)	Mean coverage (%)
Rhus aromatica	100	23.9
Festuca idahoensis	100	14.9
Agropyron spicatum	100	55.7
Bromus japonicus	100	19.2
Carex heliophila	100	12.7
Poa canbyi	100	7.8
Bouteloua curtipendula	100	2.0
Koeleria pyramidata	100	2.0
Aster ericoides	100	0.3
Agropyron smithii	100	0.2

Shrubs and graminoids are most conspicuous in the *R. aromatica/F. idahoensis* habitat type (table 1).

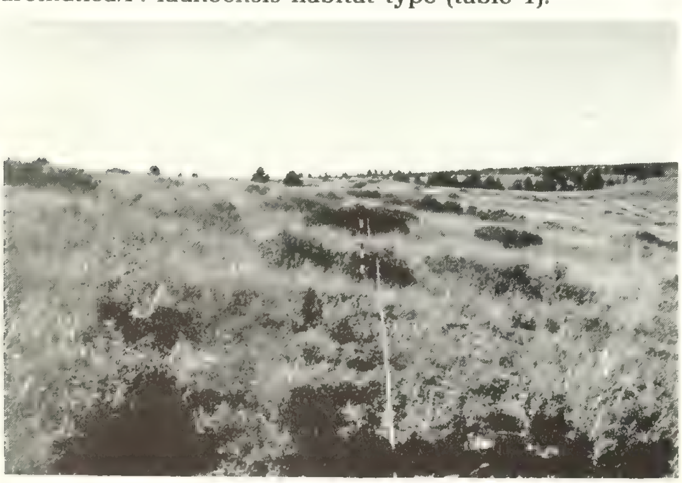

Figure 20.—*Rhus aromatica/Festuca idahoensis* habitat type on gently rolling hillsides, Ashland District, Custer National Forest. Note the wide spacing of *R. aromatica* in this stand.

Figure 21.—*Rhus aromatica/Carex filifolia* habitat type, Slim Buttes, Sioux District, Custer National Forest. *C. filifolia* provides 43% coverage in the undergrowth.

Stands of *R. aromatica/F. idahoensis* are readily accessible to livestock, and various levels of disturbance are apparent. Overgrazing usually reduces the abundance of *F. idahoensis* and *A. spicatum* and increases that of *Bromus japonicus, Gutierrezia sarothrae, Artemisia frigida, Ambrosia psilostachya,* and *Cerastium arvense.*

The soils are sandy loams (table A–26).

Mueggler and Stewart (1980) described a *R. aromatica/F. idahoensis* habitat type occurring along sedimentary benchlands or terraces above tributaries of the Yellowstone and Missouri Rivers in south-central Montana. Their stands of the habitat type are similar in both physiognomy and vegetation to these of the present study.

Rhus aromatica/Carex filifolia

This also is an infrequent habitat type that occurs as patches or strips on convex shoulders and moderate to steep slopes in the central portion of the study region (fig. 21). Locally abundant stands in the *Rhus aromatica/Carex filifolia* habitat type are found in the Slim Buttes area. Considerable amounts of rock and mineral soil are exposed on the soil surface.

The *R. aromatica/C. filifolia* habitat type is characterized by widely spaced *R. aromatica*, 1 to 2 feet (3 to 6 dm) tall, and by the low-growing *C. filifolia.* Other shrubs, such as *Artemisia frigida, Rosa arkansana,* and *Gutierrezia sarothrae,* may be present but have coverages of 5% or less. *C. filifolia,* the most abundant graminoid, is accompanied by the constant *Muhlenbergia cuspidata, Stipa comata, Koeleria pyramidata,* and *Agropyron dasystachyum.* Conspicuous forbs, but with very low coverage, are *Echinacea angustifolia, Petalostemon purpureus,* and *Phlox andicola.* Ordinarily, the graminoids *A. dasystachyum* and *C. heliophila* are restricted to areas under canopies of *R. aromatica.* Several unions are represented in this habitat type, including *R. aromatica, C. filifolia, Agropyron smithii, Stipa comata, Andropogon scoparius,* and the *Juniperus horizontalis.*

In the four stands sampled, 56 species were recorded (table A–14) and 30 species had constancies of 50% or

higher. Major species and their constancy and mean coverage percentages are as follows:

Species	Constancy (%)	Mean coverage (%)
Rhus aromatica	100	25.1
Carex filifolia	100	43.3
Muhlenbergia cuspidata	100	14.1
Stipa comata	100	7.5
Artemisia frigida	100	4.0
Koeleria pyramidata	100	3.8
Agropyron dasystachyum	100	3.3
Artemisia dracunculus	100	0.6
Echinacea angustifolia	100	0.4
Petalostemon purpureus	100	0.3
Bouteloua gracilis	75	4.5

As in other *R. aromatica*-dominated habitat types, graminoids provide considerably more coverage than either shrubs or forbs (table 1).

The soil textures of the four stands are all sandy loams (table A–26). The *R. aromatica/C. filifolia* plant association is a topoedaphic climax.

Mueggler and Stewart (1980) reported no *R. aromatica/C. filifolia* from western Montana, and Hansen et al. (1984) found no *R. aromatica*-dominated vegetation in Theodore Roosevelt National Park.

Sarcobatus vermiculatus/Agropyron spicatum

The *Sarcobatus vermiculatus/Agropyron spicatum* habitat type is limited in both size and extent. This infrequent habitat type is restricted to contoured microbenches, 1 to 1.64 feet (3 to 5 dm) wide, on moderate to steep southwest- to southeast-facing hillsides in the western portion of the study region (fig. 22). The contouring microbenches result from nonuniform erosion of clay and silt shale layers. These are interspersed with occasional seams of lignite varying in thickness from a few centimeters to over a meter. The porous lignite seams cause subsurface water to move horizontally to the surface on the hillsides. The increased moisture content favors the development of the mesophytic *S. vermiculatus* on generally xeric sites.

Figure 22.—*Sarcobatus vermiculatus/Agropyron spicatum* habitat type on a contouring microbench, Ashland District, southeastern Montana.

The *S. vermiculatus/A. spicatum* vegetation consists of irregularly spaced *S. vermiculatus*, 2 to 3.28 feet (6 to 10 dm) in height, and a wide scattering of the caespitose *A. spicatum*. Coverage values for the two species are 25.8% and 16.3%, respectively (table A–15). Other shrubs present may include *Atriplex confertifolia, Artemisia tridentata*, and *Gutierrezia sarothrae*.

In the three stands sampled, only 14 species were recorded (table A–15) and six species had constancies of 67% or higher. Major species of the *Sarcobatus vermiculatus/Agropyron spicatum* habitat type and their constancy and mean coverage percentages are as follows:

Species	Constancy (%)	Mean coverage (%)
Sarcobatus vermiculatus	100	25.8
Agropyron spicatum	100	16.3
Atriplex confertifolia	100	6.7
Artemisia tridentata	100	3.9
Gutierrezia sarothrae	67	1.4
Oryzopsis hymenoides	67	0.5

As indicated, shrubs are well represented in this habitat type. The *S. vermiculatus/A. spicatum* and the *Juniperus horizontalis/Carex heliophila* plant associations represent the only shrub-steppe vegetation in this study in which the shrub coverage exceeds the graminoid coverage. Forbs are most poorly represented, as shown by their low mean coverage value (table 1).

Typically, stands of *S. vermiculatus/A. spicatum* are contiguous with stands of the *Artemisia tridentata/Agropyron spicatum* habitat type. The steep hillsides limit the influence of cattle grazing.

Soil textures for the three stands are clay and clay loams. High amounts of exchangeable calcium and magnesium in the soils result in a high cation exchange capacity. The soils also have large amounts of rock and exposed lignite. In the stands sampled, the exposed soil surface ranges from 52% to 77%. Due to both topographic and edaphic characteristics, the plant association is a topoedaphic climax (table A–26).

Other investigators have described *S. vermiculatus*-dominated vegetation. In the badland vegetation in southeastern Montana, Brown (1971) described a community dominated by *S. vermiculatus* with *Artemisia tridentata, Suaeda fruticosa*, and *Atriplex confertifolia*, along with limited amounts of *Agropyron spicatum* present. In the steppe region of eastern Washington, Daubenmire (1970) identified a *S. vermiculatus/Distichlis spicata* habitat type occurring on saline-alkali soils. In western Montana, Mueggler and Stewart (1980) identified a *S. vermiculatus/Agropyron smithii* habitat type occurring on nearly level floodplains of rivers and streams, and a *Sarcobatus vermiculatus/Elymus cinereus* habitat type occupying concave toe slopes just above floodplains of rivers and streams.

Sarcobatus vermiculatus/Agropyron smithii

This habitat type occurs primarily on alluvial deposits of terraces, fans, and floodplains of the major streams

and rivers throughout the western portion of the study region (fig. 23). Many of the stands are quite extensive, covering large areas of the landscape. Only two stands were sampled but several others were observed. In the study area, ranch headquarters frequently are located on the floodplains and many sites in this habitat type are farmed or used as haylands. Other stands are readily accessible to livestock and most sites show various degrees of disturbance. The *S. vermiculatus/A. smithii* habitat type supports the fewest plant species of the habitat types identified in the present study. The *S. vermiculatus* and *A. smithii* unions only are represented in this plant association. In the two stands sampled, only 13 species were recorded (table A–15). *S. vermiculatus*, 2 to 3.28 feet (6 to 10 dm) in height, dominates the shrub layer and the rhizomatous *A. smithii* dominates the herbaceous layer. The palatable *A. smithii* and *Poa canbyi* decrease as a result of grazing, while *Bouteloua gracilis, Achillea millefolium, Camelina microcarpa, Opuntia polyacantha,* and the introduced annuals *Bromus japonicus* and *B. tectorum* all increase. Major species of this habitat type and their constancy and mean coverage percentages are as follows:

Species	Constancy (%)	Mean coverage (%)
Sarcobatus vermiculatus	100	23.2
Agropyron smithii	100	50.3

Shrubs and graminoids are most conspicuous in the *S. vermiculatus/A. smithii* habitat type, and forbs are poorly represented (table 1).

Soil textures for the two stands are classified as loams (table A–26). Soils have relatively high pH values of 8.0 to 8.4, respectively. The *S. vermiculatus/A. smithii* plant association is an edaphic climax.

Mackie (1970) identified a *S. vermiculatus/A. smithii* habitat type in north-central Montana occurring on floodplains of the Missouri River and its major tributaries. In western Montana, Mueggler and Stewart (1980) described a *S. vermiculatus/A. smithii* habitat type occurring as narrow bands along floodplains of rivers and streams. Vegetation of the habitat type defined by Mueggler and Stewart is similar to that of the *S. vermiculatus/A. smithii* habitat type of the present study. Jorgenson (1979) described a *S. vermiculatus/Agropyron dasystachyum* habitat type on alluvial deposits on the Yellow Water Triangle, Montana in which *A. smithii* also was an important component of the undergrowth.

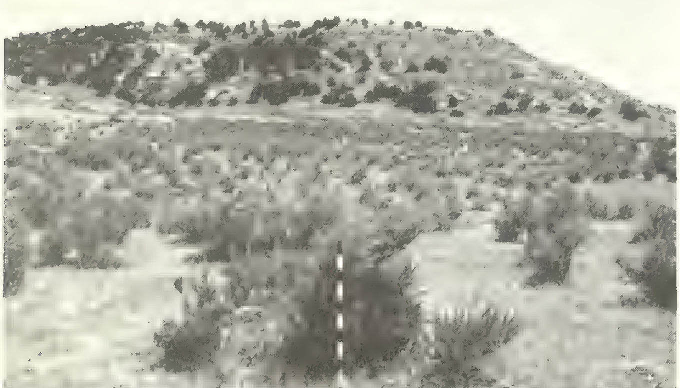

Figure 23.—*Sarcobatus vermiculatus/Agropyron smithii* habitat type on an alluvial deposit along a tributary of the Tongue River, Ashland District, southeastern Montana.

Figure 24.—Interior of a stand on the *Juniperus scopulorum/Agropyron spicatum* habitat type, Ashland District, Custer National Forest. Stands on this habitat type are characteristically open with limited undergrowth.

Woodland Habitat Types

Juniperus scopulorum/Agropyron spicatum

This habitat type occurs on moderate to steep north-facing slopes along the major drainages in the western portion of the study region. In the four stands sampled in the *Juniperus scopulorum/Agropyron spicatum* habitat type, the slopes ranged from 38% to 48%. Undisturbed stands are characterized by widely scattered individuals of *J. scopulorum*, 9.8 to 13.1 feet (3 to 4 m) in height, interspersed with the caespitose *A. spicatum* (fig. 24). The stands are open, and considerable amounts of rock and mineral soil are exposed at the soil surface (table A–16). *J. scopulorum* usually forms dense, irregular, pyramidal or conical crowns with many branches originating at or near the soil surface. In many stands, the main trunks of the larger trees were cut long ago for use as fenceposts. After disturbance, *Gutierrezia sarothrae, Symphoricarpos occidentalis, Achillea millefolium,* and *Cerastium arvense* increase in abundance. Erosional damage is evident in most of the stands.

In the four stands sampled, 62 species were recorded (table A–16) and 23 undergrowth species had constancies of 50% or higher. Major undergrowth species of this habitat type and their constancy and mean coverage percentages are as follows.

Species	Constancy (%)	Mean coverage (%)
Agropyron spicatum	100	28.2
Achillea millefolium	100	0.9
Cerastium arvense	100	0.6
Gutierrezia sarothrae	100	0.4
Symphoricarpos occidentalis	75	1.0
Bouteloua curtipendula	50	1.1

Compared to other plant associations studied, *J. scopulorum/A. spicatum* has the lowest undergrowth coverage, with values ranging from 32% to 55% (table 1).

Most stands show evidence of past fires. Young *J. scopulorum* is easily killed by fire because of small size, thin bark, and compact crown, and it does not resprout after a fire (Fischer and Clayton 1983, Wright et al. 1979). With thicker bark and less compact foliage, older *J. scopulorum* can be killed by a hot fire but can survive a cool fire. Mature *J. scopulorum* survived up to six separate fires in one study (Fischer and Clayton 1983). Sparse surface fuels reduce the chances of a damaging fire, but low spreading branches provide a route for fire to enter the crown and increase the potential for damage even in a cool fire.

The largest *J. scopulorum* sampled were in the 20– to 24–inch (5– to 6–dm) d.b.h class (table A–1); most trees were in the 8– to 12–inch (2– to 3–dm) d.b.h. class. Tree basal areas for these open stands ranged from 39.2 to 108.9 square feet per acre (9.0 to 25.0 m^2/ha). Many of the trees were more than 120 years old, and some were more than 390 years old.

Soil textures for the four stands are classified as clay loams and loams (table A–26). The *J. scopulorum/A. spicatum* plant association is a topographic climax.

Other investigators have described *J. scopulorum*-dominated vegetation (Alexander et al. 1986, Brown 1971, Hansen et al. 1984, Pfister et al. 1977, Steele et al. 1983); some have reported *J. scopulorum* as either a codominant or the major understory dominant (Brown 1971; Hoffman and Alexander 1976, 1983, 1987; Mackie 1970; Roberts and Sibbernsen 1979). In badlands of the Ashland District of the Custer National Forest, Brown (1971) described a *J. scopulorum/A. spicatum* community occurring in the deeper channels of side drainages. The physiognomy of the *J. scopulorum/A. spicatum* habitat type is similar to that of the *Pinus-Juniperus* stands of the Southwest, although *Pinus* is absent.

Juniperus scopulorum/Oryzopsis micrantha

This infrequent habitat type occurs on moderate to steep north-facing slopes of 30% to 65% in the central portion of the study region. Undisturbed stands have a closed overstory dominated by *Juniperus scopulorum*, 9.8 to 13.1 feet (3 to 4 m) in height, with *Oryzopsis micrantha* as the important undergrowth species; mosses and lichens may be locally abundant (fig. 25). *Agropyron spicatum* is absent from this habitat type. This plant association is characterized by the *J. scopulorum* and *O. micrantha* unions. The stands typically have considerable amounts of rock and mineral soil exposed at the soil surface. In the three stands sampled, 44 species were recorded (table A–17).

The physiognomy of the *J. scopulorum/O. micrantha* plant association differs from that of the *J. scopulorum/A. spicatum* in having a closed canopy. This difference is obvious in mean basal areas; 143.8 square feet per acre (33.0 m^2/ha) for the *J. scopulorum/O. micrantha* plant association and 81.5 square feet per acre (18.7 m^2/ha) for *J. scopulorum/A. spicatum* (table A–1). Additionally, the microclimate of the *J. scopulorum/O. micrantha* habitat type on mesic north-facing slopes is suitable for such mesophytic species as *O. micrantha*, *Campanula rotundifolia*, *Smilacina stellata*, *Galium boreale*, and abundant mosses and lichens.

Figure 25.—Interior of a stand on the *Juniperus scopulorum/Oryzopsis micrantha* habitat type, Long Pines, Sioux District, Custer National Forest. *J. scopulorum* has produced a closed canopy in this stand.

Three stands were sampled in which 18 undergrowth species had constancies of 67% or higher. Constancy and mean coverage percentages of the major plants of this habitat type are as follows:

Species	Constancy (%)	Mean coverage (%)
Oryzopsis micrantha	100	46.2
Campanula rotundifolia	100	0.8
Mosses and lichens	67	14.4
Smilacina stellata	67	2.6
Galium boreale	67	0.1

Compared to other habitat types in this region, forbs are well represented, though graminoids provide the greatest coverage (table 1).

J. scopulorum/O. micrantha-dominated stands had 44 undergrowth species with coverage sums of 65% to 88% (table A–17). *J. scopulorum/A. spicatum*-dominated stands were richer with 62 species but had lower coverage sums of 33% to 55% (table A–16).

In many stands of the *J. scopulorum/O. micrantha* habitat type, larger trees have been cut and removed for fenceposts. Limited livestock grazing occurs, but owing to the steep slopes and the dense cover by *J. scopulorum*, the stands are used primarily by game species. There are numerous game trails throughout the stands, and *Achillea millefolium* and *Artemisia frigida* are most abundant along these trails. The shrubs *Berberis repens*, *Ribes cereum*, *Symphoricarpos albus*, *S. occidentalis*, and the graminoid *Carex heliophila* are considered accidental or seral species, and they occur most abundantly in the vicinities of openings in the *J. scopulorum* canopy. The largest *J. scopulorum* sampled was in the 12– to 16–inch (3– to 4–dm) d.b.h. class; most trees were in the 8– to 12–inch (2– to 3–dm) d.b.h. class (table A–1). Tree basal

areas for the stands varied from 98.4 to 181.2 square feet per acre (22.6 to 41.6 m^2/ha). Many of the trees were more than 100 years old, and some were more than 270 years old.

Soil textures of the three stands are loam and sandy loams (table A–26). Owing to its unique topographic position, the *Juniperus scopulorum/Oryzopsis micrantha* plant association is a topographic climax.

Hansen et al. (1984) described this habitat type in Theodore Roosevelt National Park of western North Dakota where, as a topographic climax, the association is abundant on moderate to steep northwest- to north-facing slopes. In the North Dakota study, the undergrowth coverage sums ranged from 127% to 204% compared to 65% to 85% in the present study. The mean coverage values for mosses plus lichens were 72.5% and 14.4% in the North Dakota and present study, respectively. The lower values in this study reflect the influence of a slightly drier environment and the possible influences of both livestock and humans.

Fraxinus pennsylvanica/Prunus virginiana

In the northern Great Plains where zonal soils support steppe vegetation, woodland vegetation is confined to stream courses or to other positions in the landscape where combinations of soil and topography permit greater than average accumulation of moisture. The *Fraxinus pennsylvanica/Prunus virginiana* habitat type occurs in upland ravines and broad valleys or moderately steep slopes throughout the study area (fig. 26). It also occurs along small permanent or ephemeral streams.

In the 14 stands sampled, 90 species were recorded (table A–18). The tree stratum is dominated by the *F. pennsylvanica* union, which includes *Acer negundo* and *Ulmus americana*. In sharply cut, V-shaped upland ravines, the largest *F. pennsylvanica* are near the center or bottom of the ravine where there is greater soil moisture. In relatively undisturbed stands, the undergrowth is comprised of two layers. The taller and more conspicuous layer is 6.6 to 9.8 feet (2 to 3 m) in height and is composed chiefly of *P. virginiana*, with a mean coverage of 52.8%. Its abundance and stature are indicative of the *F. pennsylvanica/P. virginiana* plant association (fig. 27). Other members of the *P. virginiana* union are *Rosa woodsii*, *Amelanchier alnifolia*, and *A. sanguinea*. *Carex sprengelii* and *Elymus virginicus* dominate the lowest layer, with mean coverages of 31.8% to 14.1%, respectively. Other members of the *C. sprengelii* union characteristic of this vegetation are *Agropyron caninum*, *Thalictrum dasycarpum*, *T. venulosum*, *Smilacina stellata*, *Galium aparine*, and *Parietaria pennsylvanica*. Along the fringes of these stands, *Prunus virginiana* frequently forms dense ecotonal thickets before giving way to steppe vegetation higher on the slopes. In characterizing this habitat type, samples must be taken well within the mature overstory woodland vegetation, because not only are many stands very narrow, but the moisture gradient upslope onto adjacent steppe is quite steep. Sampling from the center of the *F. pennsylvanica*-dominated stand upslope toward the steppe can obliterate recognition of the rather distinct ecotones separating the long, narrow strips of vegetation.

Figure 26.—Occurrence of the *Fraxinus pennsylvanica/Prunus virginiana* habitat type within the general landscape, Grand River District, Custer National Forest.

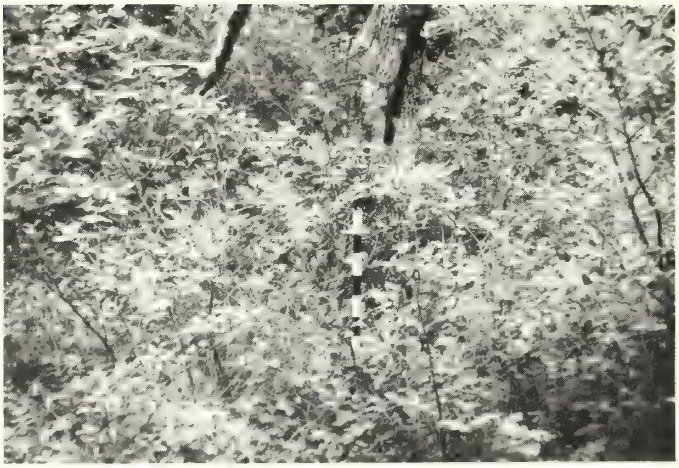

Figure 27.—Interior of an undisturbed stand of the *Fraxinus pennsylvanica/Prunus virginiana* habitat type. The undergrowth is a rich mixture of shrubs and herbaceous species.

In the central and western portions of the study region, *Crataegus succulenta* is abundant in many stands, and observations along fence lines of exclosures indicate it increases following overgrazing by livestock.

Fourteen stands were sampled, with only 12 undergrowth species having a constancy of 50% or higher. Constancy and mean coverage percentages of the major species of the *F. pennsylvanica/P. virginiana* plant association are as follows:

Species	Constancy (%)	Mean coverage (%)
Prunus virginiana	93	52.8
Carex sprengelii	100	31.8
Elymus virginicus	86	14.1
Smilacina stellata	86	3.0
Galium aparine	79	6.3
Agropyron caninum	71	4.4
Parietaria pennsylvanica	64	1.4
Thalictrum dasycarpum	64	0.7
Rosa woodsii	50	1.0

The means of shrub, graminoid, and forb coverages are shown in table 1.

Of the 14 stands sampled, stands 7, 9, 27, 28, 84, 110, and 115 are located within exclosures. The *F. pennsylvanica/P. virginiana* vegetation is rich in shrubs (26 species). The mean coverage of shrubs in the exclosures was 103.0%, the mean for all 14 stands was 78.9%, and the mean for stands not in exclosures was 57%. In contrast, the values for the graminoids and forbs were nearly identical.

The largest *F. pennsylvanica* sampled was in the 20- to 24-inch (5- to 6-dm) d.b.h. class (table A-1) and was 114 years. Tree basal area for the 14 stands ranged from 67.5 to 195.2 square feet per acre (15.5 to 44.8 m^2/ha). The average age of *F. pennsylvanica* was 70 to 80 years. However, heartrot prevented determining the ages of many of the larger trees. Soil textures are clay loams, loams, sandy clay loam, and sandy loam (table A-26). The *F. pennsylvanica/P. virginiana* plant association is a topoedaphic climax.

Hansen et al. (1985) described this habitat type for Theodore Roosevelt National Park of western North Dakota. This report is the first recognition of the *F. pennsylvanica/P. virginiana* habitat type in either Montana or South Dakota.

In the northern Great Plains, upland woodlands and forests are important in the overall landscape mosaic, even though they represent a very small fraction of the total area. Located in areas of greater than normal moisture, they are more productive than the surrounding steppe vegetation (Thomas et al. 1979). They add to the overall diversity of the vegetation. They also attract wildlife and domestic animals for the thermal cover, nesting habitat, moisture, browse species, and protection they afford (Ames 1977, Hansen et al. 1985, Severson and Boldt 1978). Because of this, these woodlands and forests are focal points for some of the livestock and wildlife management conflicts in this region.

Livestock grazing has had adverse effects on these sites for both wildlife and vegetation maintenance. Heavy cattle grazing significantly reduces bird species composition and foraging guilds, as well as small mammal density and diversity (Kauffman and Krueger 1984). Livestock grazing also influences soil compaction and bulk density. Alderfer and Robinson (1949), Bryant et al. (1972), Orr (1960), and Rauzi and Hanson (1966) all found soil compaction increased linearly with increases in grazing intensity.

Livestock grazing of these upland woodlands resulted in reduced coverage and some changes in the species composition (fig. 28). In this study, three heavily grazed stands of this habitat type were sampled (table A-19). In all three, the shrub species were greatly reduced. The mean shrub coverage of 79% in undisturbed stands contrasts with 10% in the heavily grazed stands, where most of the coverage was the unpalatable *Symphoricarpos occidentalis*. Mean graminoid coverage of 75% in undisturbed stands contrasts to 10% in disturbed stands, most of which consists of *Poa pratensis*. Overall, the sum of the mean coverages of shrubs, graminoids, and forbs was 187% in undisturbed stands compared to 123% in

Figure 28.—Interior of a disturbed stand of the *Fraxinus pennsylvanica/Prunus virginiana*. Many shrubs have been severely browsed or eliminated and tree reproduction sharply reduced.

Figure 29.—Severe overgrazing has eliminated most of the undergrowth and tree reproduction in this stand of the *Fraxinus pennsylvanica/Prunus virginiana* habitat type. Undergrowth in this open stand is now dominated by *Symphoricarpos occidentalis* and *Poa pratensis*.

heavily grazed stands (tables A-18 and A-19). In the three grazed stands, 42 species were recorded; 10 species had constancies of at least 67%. Major species in these three stands are as follows:

Species	Constancy (%)	Mean coverage (%)
Poa pratensis	100	83.1
Symphoricarpos occidentalis	100	5.5
Stipa viridula	100	3.1
Achillea millefolium	100	1.8
Bromus japonicus	100	0.6
Agropyron caninum	67	10.1
Monarda fistulosa	67	0.7

The continued decline in the understory shrubs, tree seedlings, and saplings eventually results in a stand of only older trees, a very open understory, and a low shrub and herbaceous layer (fig. 29). Reducing the seedling-sapling component of the overstory species can only result eventually in a decline of the tree population, opening the stand to greater insolation at the ground surface,

and increasing reproduction of heliophytic herbaceous species. Indeed, "former" woodlands have been observed in this state of decadence. Others apparently have observed the same phenomenon elsewhere (Crouch 1979, Richard and Cushing 1982). Intense cattle grazing reduces the value of this resource for further cattle grazing or wildlife, as indicated above.

Populus tremuloides/Berberis repens

This infrequent habitat type occurs in upland ravines, on moderately steep slopes, and along small permanent or ephemeral streams in the central portion of the study region; small isolated stands may be found in the eastern and western portions (fig. 30). Most stands are on north exposures. In the four stands sampled, 59 species were recorded (table A–20). The *Populus tremuloides/Berberis repens* habitat type is recognized by the consistent presence and reproductive success of *P. tremuloides*, the only member of its union, and the abundance and dominance of the *B. repens* union in the undergrowth. Other members of the *B. repens* union include *Symphoricarpos albus*, *Rubus idaeus*, *Toxicodendron rydbergii*, and *Ribes missouriense*. The *Prunus virginiana* and the *Carex sprengelii* unions also are represented. Because of livestock grazing, *Poa pratensis* also is abundant in this habitat type. Other important forbs include *Galium boreale* and *Smilacina stellata*.

Four stands were sampled, with 30 undergrowth species having constancies of 50% or higher. Major species of this habitat type and their constancy and mean coverage percentages are as follows:

Species	Constancy (%)	Mean coverage (%)
Berberis repens	100	45.4
Poa pratensis	100	36.1
Galium boreale	100	5.8
Prunus virginiana	100	5.1
Symphoricarpos albus	100	4.4
Rubus idaeus	100	2.3
Toxicodendron rydbergii	100	1.2
Ribes missouriense	100	0.7
Smilacina stellata	100	0.2
Carex sprengelii	75	8.8
Elymus virginicus	75	5.3
Thalictrum dasycarpum	75	1.4
Amelanchier alnifolia	50	0.6
Amelanchier sanguinea	50	0.5

The *P. tremuloides/B. repens* plant association is rich in shrubs; 19 species were recorded. Graminoids and forbs also are well represented (table 1).

There has been considerable discussion regarding the role of *P. tremuloides* in the West as both a climax and a seral species, and both assessments may be correct. There is sufficient evidence that *P. tremuloides* invades or is established on favorable sites after fire (Hoff 1957; Hoffman and Alexander 1976, 1980, 1983, 1987; Morgan 1969; Mueggler and Bartos 1977; Mueggler and Campbell 1982, 1984; Severson and Thilenius 1976; Youngblood and Mueggler 1981). In some areas, *P. tremuloides* dominates sites where fires have destroyed coniferous forests, and, in time, the conifers gradually replace *P. tremuloides*. On other sites, *P. tremuloides* forests appear to be self-perpetuating climax without evidence of conifer invasion.

Figure 30.—*Populus tremuloides/Berberis repens* habitat type in the Ekalaka Hills, Sioux District, Custer National Forest. *P. tremuloides* occurs in diameter classes ranging from 0–1 to 3–4 dm.

In the study area, stands of the *P. tremuloides/B. repens* habitat type apparently are stable with *P. tremuloides* present in all size classes (table A–1). In other stands, *Fraxinus pennsylvanica* or *Acer negundo* may be widely scattered. The presence of *F. pennsylvanica* or *A. negundo* seems to indicate past disturbance. For example, in stands 53 and 54, abundant *F. pennsylvanica* and *A. negundo* occur near openings of the canopy caused by windthrow of the taller *P. tremuloides*. Immediately after disturbance, *F. pennsylvanica*, *A. negundo*, and *P. tremuloides* all produce abundant seedlings and/or root suckers. The canopy eventually is closed by *P. tremuloides*, and numerous seedlings and/or saplings of *F. pennsylvanica* and *A. negundo* die. In stands 53 and 54, there were 29 and 133 dead trees, respectively, of *F. pennsylvanica* and/or *A. negundo*. This is interesting because both *F. pennsylvanica* and *A. negundo* reproduce adequately in their own shade to replace their numbers in the overstory. *P. tremuloides* obviously is an effective competitor in this habitat type. A few scattered saplings of *F. pennsylvanica* or *A. negundo* may survive to maturity and reproduce following future disturbances.

Stands of the *P. tremuloides/B. repens* habitat type are accessible to livestock that move in for the same reasons indicated for the *F. pennsylvanica/Prunus virginiana* habitat type. Abundant *Poa pratensis* is the result of grazing disturbance in the *P. tremuloides/B. repens* habitat type.

The largest *P. tremuloides* sampled was in the 12– to 16–inch (3– to 4–dm) d.b.h. class (table A–1). Tree basal areas for the four stands ranged from 139.0 to 230.4 square feet per acre (31.9 to 52.9 m²/ha). Most of the trees were more than 60 years old, and few were more than 95 years old. However, heartrot made age determination difficult in many of the larger *P. tremuloides*. The soil textures are sandy loams (table A–26). The *P.*

tremuloides/B. repens plant association is considered to be a topographic climax.

P. tremuloides forests with somewhat similar undergrowth vegetation occur in the Black Hills National Forest (Hoffman and Alexander 1987). In western North Dakota, Hansen et al. (1984) described a *P. tremuloides/Betula occidentalis* habitat type that shares many of the common undergrowth species except *Betula occidentalis* and *Berberis repens*. Throughout the Rocky Mountain West, others have defined a similar *P. tremuloides/Symphoricarpos oreophilus* habitat type with *B. repens* prominent in the undergrowth (Hoffman and Alexander 1980, 1983; Reed 1971). Mueggler and Campbell (1982, 1984) and Youngblood and Mueggler (1981) described a *P. tremuloides/S. oreophilus* community type for southeastern Idaho, Utah, and western Wyoming, and indicated it probably was stable and very likely a habitat type.

Forest Habitat Types

In the study area, *Pinus ponderosa* forests are relatively uncommon, and where they occur, they form a mosaic with steppe, shrub-steppe interspersed (fig. 31). In the western part of the region, *P. ponderosa* is more common and some of the stands are extensive.

Pinus ponderosa/Agropyron spicatum

The *Pinus ponderosa/Agropyron spicatum* habitat type commonly occurs on moderate to steep south-facing slopes in the western portion of the study region; infrequent stands also occur in the central portion. This habitat type is the most xeric of those dominated by *P. ponderosa*. The slope position of this habitat type varies from a band along the summit of hills to an entire hillside (fig. 32). The soils are commonly coarse-textured or rocky, and many have large amounts of reddish iron oxide porcelainite material. Considerable amounts of rock and mineral soil usually are exposed on the soil surface. In relatively undisturbed stands, widely spaced *P. ponderosa* occupies the tallest layer; an occasional Juniperus scopulorum may be present. The *Agropyron spicatum*, *Carex heliophila*, and *Andropogon scoparius* unions characterize the sparse undergrowth. *Agropyron spicatum* is most conspicuous, and *Carex heliophila*, *Rhus aromatica*, and *Bouteloua curtipendula* provide limited coverage.

Figure 31.—General view of typical scattered *Pinus ponderosa* stands, Ashland District, southeastern Montana.

Figure 32.—*Pinus ponderosa/Agropyron spicatum* habitat type on a steep south-facing slope, Ashland District, Custer National Forest. Undergrowth is dominated by graminoids.

In the three stands sampled, 48 species were recorded (table A–21, appendix 2); only nine undergrowth species had constancies of 50% or higher. Major species of the *P. ponderosa/A. spicatum* habitat type and their constancy and mean coverage percentages are as follows:

Species	Constancy (%)	Mean coverage (%)
Agropyron spicatum	100	32.4
Carex heliophila	100	14.7
Bouteloua curtipendula	67	1.4

Overall, the vegetation of this warm, dry habitat type is rather sparse; graminoids are most conspicuous (table 1).

Except for the dominance of *P. ponderosa*, this habitat type is similar in vegetation and topographic position to both the *A. spicatum/Bouteloua curtipendula* and the *Rhus aromatica/A. spicatum* habitat types. *P. ponderosa* seedlings establishing in some steppe locations currently dominated by *A. spicatum* indicate a possible succession to *P. ponderosa*. The history of this steppe is not known; it is possible that *P. ponderosa* once occurred here and was eliminated by fire, logging, grazing, or a combination of these.

The largest *P. ponderosa* sampled was in the 24– to 28–inch (6– to 7–dm) d.b.h. class (table A–1). The basal areas for the three stands sampled ranged from 134.6 to 160.3 square feet per acre (30.9 to 36.8 m^2/ha). The low basal areas reflect the xeric microclimate and the open vegetation. Many of the trees were more than 100 years old, and some were more than 200 years old. Soil textures are loamy sand, sandy loam, and sand (table A–26). The *P. ponderosa/A. spicatum* plant association is considered to be a topoedaphic climax.

A *P. ponderosa/A. spicatum* habitat type has been described for eastern Washington and northern Idaho

(Daubenmire and Daubenmire 1968), the Bighorns of north-central Wyoming (Hoffman and Alexander 1976), north-central Montana (Mackie 1970), central Montana (Jorgenson 1979), the Crow and Northern Cheyenne Indian Reservations in southeastern Montana (Cooper and Pfister 1984), other locations in Montana (Pfister et al. 1977), and central Idaho (Steele et al. 1981.

Pinus ponderosa/Festuca idahoensis

Only two stands of this habitat type were sampled, although numerous others were observed. The *Pinus ponderosa/Festuca idahoensis* habitat type occurs on gently rolling upland topography in the western portion of the study region and is not as dry as the *P. ponderosa/Agropyron spicatum* habitat type. In relatively undisturbed stands of this habitat type, widely spaced *P. ponderosa* occupy the overstory layer interspersed with an occasional *Juniperus scopulorum*. The undergrowth is characterized by the *Festuca idahoensis* and *Carex heliophila* unions (fig. 33). In the two stands sampled, 37 species were recorded (table A-22). The presence of *P. ponderosa* distinguishes this from the *F. idahoensis/C. heliophila* habitat type. The two habitat types usually are contiguous and separated by an abrupt ecotone. Constancy and mean coverage percentages of the major plants in the two stands sampled are as follows:

Species	Constancy (%)	Mean coverage (%)
Festuca idahoensis	100	41.2
Carex heliophila	100	24.5
Antennaria rosea	100	0.7

Graminoids dominate the undergrowth of this habitat type, forbs provide limited coverage, and shrubs are rare (table 1).

Many stands in this habitat type show evidence of past fire. The *P. ponderosa/F. idahoensis* habitat type occurs on gentle terrain, and many stands have been managed intensively for either timber or forage production. The largest *P. ponderosa* sampled was in the 24- to 28-inch

Figure 33.—*Pinus ponderosa/Festuca idahoensis* habitat type on nearly level upland topography, Ashland District, southeastern Montana. Graminoids dominate the undergrowth.

(6- to 7-dm) d.b.h. class (table A-1). Basal areas for the two stands were 153.3 square feet per acre (35.2 m^2/ha) and 188.2 square feet per acre (43.2 m^2/ha). As in the *Pinus/Agropyron* vegetation, low basal areas reflect the open nature of the vegetation. Many of the trees were at least 120 years old, and some were more than 190 years old.

Although tree reproduction is more consistent over time than in the *P. ponderosa/Agropyron spicatum* habitat type, it still is episodic. Stands of both the *P. ponderosa/F. idahoensis* and the *P. ponderosa/C. heliophila* habitat types (discussed below) are mosaics of dense patches of trees ("dog hair" stands), each distinctive in height and age. When young, the dense trees eliminate the undergrowth vegetation beneath them. Later, as the tree population becomes thinner and the canopy more elevated, herbaceous vegetation appears. In mature stands, the patches become so open that the trees have little influence on the steppe-like undergrowth.

Much of the soil surface usually is covered with litter and duff. Soil textures of the two stands are loam and sandy loam (table A-26). The *P. ponderosa/F. idahoensis* plant association is an edaphic climax.

A *P. ponderosa/F. idahoensis* habitat type has been described for eastern Washington and northern Idaho (Daubenmire and Daubenmire 1968), for the Bighorns of north-central Wyoming (Hoffman and Alexander 1976), for the Crow and Northern Cheyenne Indian Reservations in southeastern Montana (Cooper and Pfister 1984), for Montana (Pfister et al. 1977), and for central Idaho (Steele et al. 1981). In the Montana study, Pfister et al. (1977) described a *F. idahoensis* phase that is similar to the *P. ponderosa/F. idahoensis* habitat type of the present study.

Pinus ponderosa/Carex heliophila

This habitat type occurs on gently rolling upland topography in the central and western portion of the study area. The *Pinus ponderosa/Carex heliophila* habitat type is the most mesic of the graminoid-dominated *P. ponderosa* habitat types. In relatively undisturbed stands of this habitat type, *P. ponderosa* produces a closed overstory, while the *C. heliophila* union dominates the undergrowth (fig. 34). An occasional *Juniperus scopulorum* may be present. *Agropyron spicatum* is present, but the *Festuca idahoensis* union is not well represented, and the *Juniperus communis* union is absent. Based on both vegetation and physiognomy, the *P. ponderosa/C. heliophila* and *P. ponderosa/F. idahoensis* habitat types are similar. In the three stands sampled, 34 species were recorded (table A-22).

In the three stands sampled, only five undergrowth species had constancies of 50% or higher. Major species of this habitat type and their constancy and mean coverage percentages are as follows:

Species	Constancy (%)	Mean coverage (%)
Carex heliophila	100	74.9
Agropyron spicatum	100	1.1

Undergrowth of the *P. ponderosa/C. heliophila* habitat type is dominated by graminoids; forbs and shrubs are poorly represented (table 1).

Many of the stands in this habitat type show evidence of past fire. In the central portion, and to a limited degree in the western portion, of the study region, *P. ponderosa* is becoming established in stands of *Andropogon scoparius/C. heliophila* habitat type. These stands appear to represent seral stages of the *P. ponderosa/C. heliophila* habitat type rather than stands of the *A. scoparius/C. filifolia* habitat type. In these situations, *P. ponderosa* is not "invading" the *Andropogon*-dominated grassland, but is reestablishing on sites where it occurred before it was eliminated by fire. Continuous grazing since then has maintained the areas as steppe. As succession proceeds, *A. scoparius* and other heliophytes are eliminated within the shade of individual trees. The stands eventually become dominated by *P. ponderosa* and *C. heliophila*. This interpretation is based on our observations though it is possible that the climate may be changing to allow *P. ponderosa* to move into certain areas of steppe. No attempt was made to trace long-term climatic changes.

Pfister et al. (1977) described a *P. ponderosa/Andropogon* spp. habitat type occurring as a minor one in southeastern Montana in which the undergrowth is dominated by *A. scoparius* and *A. gerardii*. They reported that it occurs rarely in the Ashland District of the Custer National Forest (where one stand was sampled), but indicated that this habitat type is more common eastward in the Long Pines of the Sioux District in the Custer National Forest near the Montana-South Dakota border. In their work in southeastern Montana, Cooper and Pfister (1984) reported that the *P. ponderosa/Andropogon* spp. habitat type was only found on the eastern and southern edges of the Northern Cheyenne Indian Reservation as small and disturbed stands that preclude their being sampled. Pfister et al. (1977) reported that this habitat type replaces both the *P. ponderosa/Agropyron spicatum* and the *P. ponderosa/Festuca idahoensis* habitat types in an eastward direction toward the Black Hills, where Thilenius (1972) described a similar "habitat unit" called *P. ponderosa/Andropogon scoparius*. Based on data from the Custer National Forest and on the work of Hoffman and Alexander (1987) in the Black Hills National Forest, the *P. ponderosa/Andropogon* spp. vegetation is neither climax nor a habitat type. In the study area, this vegetation probably is seral to either the *P. ponderosa/Carex heliophila* or the *P. ponderosa/Agropyron spicatum* plant association.

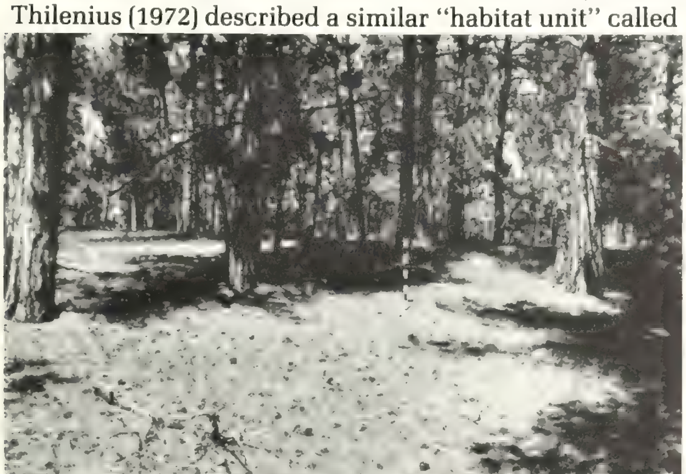

Figure 34.—*Pinus ponderosa/Carex heliophila* habitat type on gently rolling upland topography, Ekalaka Hills, Sioux District, Custer National Forest. Dominance of *C. heliophila* in the undergrowth is evident.

The episodic tree reproduction in this habitat type is much the same as that described for the *P. ponderosa/F. idahoensis* habitat type. Owing to the gentle terrain, many stands of *P. ponderosa/C. heliophila* have been managed intensively for forage and/or timber production. The largest *P. ponderosa* sampled was in the 20- to 24-inch (5- to 6-dm) d.b.h. class (table A-1). Tree basal areas for the three stands ranged from 202.6 to 243.9 square feet per acre (46.5 to 56.0 m^2/ha), reflecting somewhat wetter conditions of this habitat type. Many of the trees were more than 100 years old; some were more than 178 years old. The soil textures are sandy loams and loamy sands (table A-26). The *P. ponderosa/C. heliophila* plant association is considered to be an edaphic climax.

The *P. ponderosa/C. heliophila* habitat type was not reported in Montana, the Bighorns of Wyoming, or central Idaho (Hoffman and Alexander 1976, Pfister et al. 1977, Steele et al. 1981). It does occur in the Black Hills National Forest (Hoffman and Alexander 1987). As indicated, it also shows similarities to the *P. ponderosa/Andropogon* spp. "habitat type" described by Pfister et al. (1977) and the *P. ponderosa/Andropogon scoparius* "habitat unit" described by Thilenius (1972). It also is similar to the *P. ponderosa/Festuca idahoensis* habitat type of the present study.

Pinus ponderosa/Juniperus communis

Only two stands of this habitat type were sampled; others were observed. The *Pinus ponderosa/Juniperus communis* habitat type occurs on gently rolling upland topography to moderately steep hillsides in the central portion of the study region. In stands that are relatively free of disturbance, the *P. ponderosa* union forms a nearly closed overstory, and the *J. communis* and *Carex heliophila* unions characterize the undergrowth (fig. 35). Species of the *Berberis repens* and the *Prunus virginiana* unions also are present. In the two stands sampled, only 28 undergrowth species were recorded (table A-23).

Constancy and mean coverage percentages of the major undergrowth plants in the two stands are as follows:

Species	Constancy (%)	Mean coverage (%)
Juniperus communis	100	39.6
Carex heliophila	100	26.0
Berberis repens	50	0.4
Amelanchier alnifolia	50	0.2
Prunus virginiana	50	0.1
Symphoricarpos albus	50	0.1

Shrubs are more constant and provide more coverage than other growth forms, though only two stands were

sampled. Graminoids provide considerably less coverage than shrubs, but much greater coverage than forbs (table 1).

Due to the gentle terrain, many stands of the *P. ponderosa/J. communis* habitat type have been managed intensively for forage and/or timber production. Following disturbance, *Prunus virginiana, Danthonia spicata,* and, to a lesser extent, *Berberis repens* quickly invade the site or increase their abundance only to decrease with time and lack of disturbance. The presence of *J. communis* is key in identifying this habitat type, and it is readily killed by fire. Before birds or other natural agents have ensured dissemination of *J. communis* seeds over a burned area of this habitat type, other shrubs may dominate the undergrowth. *Prunus virginiana* may be abundant. Seral stands in the *Pinus ponderosa/J. communis* habitat type may be mistaken for the *Pinus ponderosa/Prunus virginiana* habitat type (see below).

Trees have reproduced regularly, apparently, judging from the tree population data in table A–1. Many seedlings were present in both stands. The largest *Pinus ponderosa* sampled was in the 24– to 28–inch (6– to 7–dm) d.b.h. class (table A–1). Tree basal areas for the two stands were 237.4 square feet per acre (54.5 m^2/ha) and 243.9 square feet per acre (56.0 m^2/ha). Many of the trees were more than 100 years old, and a few were more than 220 years old.

The soil surface generally is covered with litter and duff. The soil textures are classified as sandy loams (table A–26). The *P. ponderosa/J. communis* plant association is an edaphic climax.

A habitat type with similar undergrowth vegetation was not reported for Montana (Pfister et al. 1977), though it was for the Bighorn Mountains of Wyoming (Hoffman and Alexander 1976). In the Black Hills of South Dakota and Wyoming, Thilenius (1972) described a *P. ponderosa* "habitat unit" dominated by *J. communis, Symphoricarpos albus,* and *Berberis repens.* Hoffman and Alexander (1987) reported a *P. ponderosa/J. communis* habitat type occurring on the limestone plateau region of the northwestern and western portions of the Black Hills National Forest.

Figure 35.—*Pinus ponderosa/Juniperus communis* habitat type on a gentle hillside, Ekalaka Hills, Sioux District, Custer National Forest. Undergrowth in this stand is characterized by widely spaced *J. communis* with a coverage of 40%.

Pinus ponderosa/Prunus virginiana

This habitat type commonly occurs on moderate to steep north-facing slopes and close to streams in the central and western portions of the study region; a limited number of stands occupy gently rolling upland terrain in the central portion. *Pinus ponderosa/Prunus virginiana* is the wettest of the *Pinus ponderosa*-dominated plant associations. In the five stands sampled, 59 species were recorded (table A–24). Tree populations vary; in some stands all size classes of trees are present, in other stands only two or three size classes of trees are present (table A–1). In undisturbed vegetation of this habitat type, *Pinus ponderosa* forms a closed overstory; two shrub unions characterize the undergrowth. The *Prunus virginiana* union is taller and more conspicuous and composed chiefly of *Prunus virginiana,* approximately 3.28 feet (1 m) in height, with some *Amelanchier alnifolia* and *Rosa woodsii* also present (fig. 36). As a result of browsing, *Prunus virginiana* and *A. alnifolia* may be shorter and produce many stems (fig. 37). The *Berberis repens* union forms the lower and less conspicuous shrub union; other members include *Ribes missouriense, Symphoricarpos albus,* and *Toxicodendron rydbergii. Agropyron caninum, Schizachne purpurascens, Galium boreale,* and *Smilacina stellata* are important herbaceous species. *Carex heliophila* may be abundant in stands on gently rolling uplands. The *Juniperus communis* union is absent in this habitat type.

Five stands were sampled and 16 undergrowth species had constancies of 50% or higher. Major species of the *Pinus ponderosa/Prunus virginiana* habitat type and their constancy and mean coverage percentages are as follows:

Species	Constancy (%)	Mean coverage (%)
Prunus virginiana	100	43.5
Amelanchier alnifolia	100	6.2
Galium boreale	100	4.0
Berberis repens	80	26.0
Toxicodendron rydbergii	80	6.2
Agropyron caninum	80	4.3
Rosa woodsii	80	3.6
Schizachne purpurascens	80	2.6
Ribes missouriense	80	1.1
Smilacina stellata	80	0.8
Carex heliophila	60	20.3
Symphoricarpos albus	60	1.2

The relatively high coverages reflect the mesic conditions associated with this habitat type (table 1).

Most stands showed evidence of past fires. Many of the common undergrowth species of this habitat type regenerate from subterranean organs following fire. Other plants must reestablish from seeds so their presence in seral stands is controlled, in part, by the distance of seed sources. Though aerial plant parts may be consumed during fire, *Prunus virginiana, Amelanchier alnifolia,* and *Symphoricarpos albus* resprout from surviving root crowns or rhizomes and usually increase their coverage following fire. *Berberis repens* is

moderately resistant and survives all but severe fires that both remove the duff and heat the upper soil for extended periods. The forb *Apocynum androsaemifolium* also sprouts after fire. Following a cool to moderate fire, *B. repens*, *A. androsaemifolium*, and *S. albus* sprout quickly and increase their abundance. As succession advances, these species decrease in importance, usually adjusting to prefire conditions, while *Prunus virginiana* and, to a lesser extent, *Amelanchier alnifolia* slowly increase. In addition, scattered seedlings or saplings of *Fraxinus pennsylvanica* and *Crataegus succulenta* may be found at this time. *F. pennsylvanica* and *C. succulenta* usually do not survive past saplings in the older stands, and none were sampled in our stands of this habitat type. However, mature individuals of *F. pennsylvanica* and *C. succulenta* may occur close to streams in this habitat type.

The largest *Pinus ponderosa* sampled was in the 24- to 28-inch (6- to 7-dm) d.b.h. class (table A-1). Tree basal area for the five stands ranged from 159.4 to 276.6 square feet per acre (36.6 to 63.5 m^2/ha). This is the highest basal area value for *P. ponderosa*-dominated habitat

Figure 36.—*Pinus ponderosa/Prunus virginiana* habitat type on a moderately steep north-facing slope, Ashland District, southeastern Montana. Undergrowth is dominated by *P. virginiana*, *Amelanchier alnifolia*, *Berberis repens*, *Rosa woodsii*, and *Toxicodendron rydbergii*.

Figure 37.—*Pinus ponderosa/Prunus virginiana* habitat type, Long Pines, Sioux District, Custer National Forest. Note the effect of heavy browsing on *P. virginiana* and *Amelanchier alnifolia*.

types, possibly reflecting the mesic conditions of this habitat type. Many of the trees were more than 100 years old, and some were more than 210 years old. The soil textures are loam and sandy loam (table A-26). The *Pinus ponderosa/Prunus virginiana* plant association is an edaphic climax.

Pfister et al. (1977) and Cooper and Pfister (1984) described a *Pinus ponderosa/Prunus virginiana* habitat type for southeastern Montana. In the Bighorn Mountains of Wyoming and the Black Hills National Forest of South Dakota and Wyoming, Hoffman and Alexander (1976, 1987) described a *Pinus ponderosa/Physocarpus monogynus* habitat type that shares many species with the *Pinus ponderosa/Prunus virginiana* habitat type. At the northern edge of the Black Hills south of the study area, a few stands of a *Pinus ponderosa/Prunus virginiana* community also occur (Hoffman and Alexander 1987).

Community Types

Symphoricarpos occidentalis

This community type occurs as scattered thickets throughout the study region. It is recognized by the dominant rhizomatous shrub *Symphoricarpos occidentalis*, which forms dense irregularly shaped thickets up to 3.28 feet (1 m) in height (fig. 38). *S. occidentalis* has a wide ecological amplitude, adapted to most soil textures, tolerant of imperfectly drained soils but not prolonged flooding or a permanently high water table, and tolerant of both weakly basic and weakly acidic soils (Pelton 1953, Wasser 1982). In the northern Great Plains, the species is common on mesic sites, including swale-like depressions, upland ravines, and floodplains along streams and rivers. Although it thrives in nearly full sunlight, it also tolerates the moderate shade of open forests or woodlands. It is grazing- and fire-tolerant and it increases on disturbed areas (Pelton 1953, Wasser 1982). It is strongly competitive and, in dense colonies, it often excludes other vegetation. In Minnesota, Pelton (1953) found it to move into areas of steppe and shade-out herbaceous species. Trees then established on the same areas. In the present study, these thickets were considered a community type, subject to change, because there is insufficient data to consider them other than a community type.

Although only two stands were sampled, numerous others were observed. The stands are readily accessible to livestock, and most sites show various degrees of disturbance. However, the two stands sampled are located in exclosures. Typically, the *S. occidentalis* community type has three layers: an upper layer, 1.64 to 3.28 feet (0.5 to 1.0 m) tall, dominated by *S. occidentalis*; an intermediate layer, 0.7 to 1.64 feet (0.2 to 0.5 m) tall, dominated by the introduced *Poa pratensis*; and a lower layer, 0.3 to 1.0 feet (0.1 to 0.3 m) tall, dominated by *Parietaria pennsylvanica*, *Galium boreale*, and *Artemisia ludoviciana* (table A-25). Disturbance opens the dense shrub canopy allowing forbs and graminoids to invade. Stands of this community type typically occur on sites much the same as those occupied by the *Fraxinus penn-*

Figure 38.—Dense thicket of *Symphoricarpos occidentalis* in an exclosure, Grand River District, Custer National Forest.

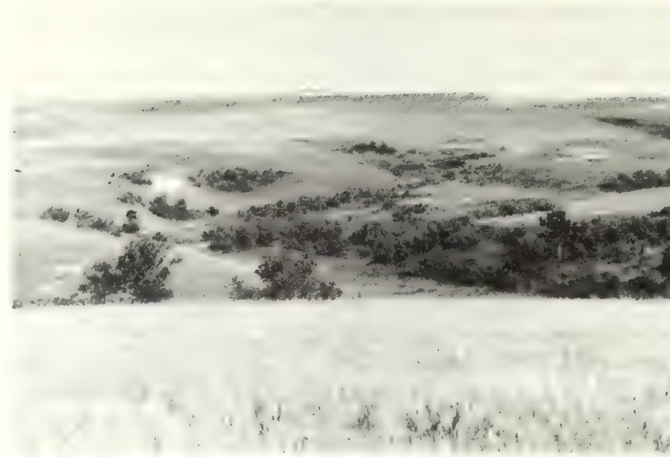

Figure 39.—Scattered thickets of *Shepherdia argentea* along an ephemeral stream, Grand River District, Custer National Forest.

sylvanica/Prunus virginiana habitat type and may be a seral stage of this habitat type. However, if the *Symphoricarpos* thickets are seral, they appear to be long-lived, and the climax vegetation is unknown.

This community type was described by Hansen et al. (1984) for western North Dakota. Thickets of *S. occidentalis* community type in steppe vegetation also have been described elsewhere (Daubenmire 1970, Mackie 1970).

Shepherdia argentea

This community type occurs as scattered thickets in the eastern and central portions of the study region; a limited number of stands also were observed in the western portion. The community type is recognized by the dominance of the spine-tipped shrub *Shepherdia argentea*, which forms dense, nearly impenetrable thickets often exceeding 6.56 feet (2 m) in height (fig. 39). *S. argentea* has a wide ecological amplitude adapted to most soil textures, but is more commonly found in well-drained medium- to coarse-textured soils. The shrub is tolerant of slightly acid to mostly basic saline soils (Wasser 1982). In the northern Great Plains, *S. argentea* occurs on mesic sites, such as swales and ravines, along ephemeral streams, and on hillsides with a northerly exposure. *S. argentea* thrives in full sunlight but may occur in shaded locations.

Eleven stands of the *S. argentea* community type were sampled (table A–25). Relatively undisturbed vegetation of this community type is characterized by a dense overstory of *S. argentea*; beneath is a scattering of *Poa pratensis* and *Parietaria pennsylvanica*. Along the edges of the stands is a rich mixture of woodland and steppe species. In some instances, *Symphoricarpos occidentalis* forms dense ecotonal thickets surrounding the stands. Livestock and deer frequent the thickets and establish numerous trails throughout. The disturbance opens the stands for the invasion of such species as *S. occidentalis, Toxicodendron rydbergii, Achillea millefolium, Artemisia ludoviciana, Monarda fistulosa, Nepeta cataria,* and *Taraxacum officinale.*

Shepherdia argentea stands occupy sites similar to the *Fraxinus pennsylvanica/Prunus virginiana* habitat type (fig. 39). While *Shepherdia*-dominated communities were classified as a community type, data to indicate the dynamics of these communities are limited. They occupy sites that appear similar to *F. pennsylvanica/P. virginiana* sites (compare figures 26 and 39), but calculated similarities between the *S. argentea* communities and those dominated by *F. pennsylvanica* are inconclusive. Using the Jaccard index of similarity, a 54% similarity was found between *S. argentea* communities and relatively undisturbed *F. pennsylvanica* communities. The *S. argentea* and undisturbed *F. pennsylvanica* communities were each 43% similar to the disturbed *F. pennsylvanica* communities. However, in a limited number of stands, widely scattered individuals of *F. pennsylvanica* were observed. Others also have described *S. argentea* thickets in the northern Great Plains (Boldt et al. 1978, Nelson 1961, Severson and Boldt 1978).

The soil textures are classified as loams, sandy loams, and loamy sands (table A–26).

Key to the Habitat Types

1. Tree species absent; graminoids, shrubs, and forbs dominant.
  2. Graminoids dominant; shrubs and forbs may be present.
    3. *Stipa comata* and/or *Agropyron smithii* dominant; *Agropyron cristatum* also may be present and abundant.
      4. *Agropyron smithii* usually dominant; if *Agropyron smithii* is absent or inconspicuous, then *Buchloe dactyloides* and *Bouteloua gracilis* are abundant and dominant. *Stipa comata* absent or inconspicuous. .... *Agropyron smithii/Carex filifolia* h.t.
      4. *Stipa comata* dominant; *Agropyron smithii* present but not dominant.
        5. *Carex filifolia* dominates the undergrowth; *Carex heliophila* absent or not abundant .... *Stipa comata/Carex filifolia* h.t.
        5. *Carex heliophila* dominates the undergrowth; *Carex filifolia* absent or not abundant .... *Stipa comata/Carex heliophila* h.t.
    3. *Stipa comata* and/or *Agropyron smithii* absent or not dominant.
      6. *Festuca idahoensis* or *Agropyron spicatum* well represented.
        7. *Festuca idahoensis* dominant; *Agropyron spicatum* absent or inconspicuous .... *Festuca idahoensis/Carex heliophila* h.t.
        7. *Agropyron spicatum* dominant; *Festuca idahoensis* absent or inconspicuous.
          8. *Bouteloua curtipendula* present and abundant; *Carex filifolia* may be present but not abundant .... *Agropyron spicatum/Bouteloua curtipendula* h.t.
          8. *Carex filifolia* abundant; *Bouteloua curtipendula* absent .... *Agropyron spicatum/Carex filifolia* h.t.
      6. *Festuca idahoensis* and *Agropyron spicatum* absent or inconspicuous.
          9. *Calamovilfa longifolia* abundant; *Andropogon scoparius* absent .... *Calamovilfa longifolia/Carex heliophila* h.t.
          9. *Andropogon scoparius* dominant; *Calamovilfa longifolia* inconspicuous or absent .... *Andropogon scoparius/Carex filifolia* h.t.
  2. Shrubs dominant; graminoids and forbs usually present.
    10. *Artemisia tridentata* or *Artemisia cana* present and conspicuous; other shrubs absent or rare.
      11. *Artemisia tridentata* dominant; *Artemisia cana* absent or inconspicuous.
        12. *Agropyron spicatum* dominant in the low undergrowth; *Agropyron smithii* inconspicuous or absent .... *Artemisia tridentata/Agropyron spicatum* h.t.
        12. *Agropyron smithii* dominant in the undergrowth; *Agropyron spicatum* absent or inconspicuous .... *Artemisia tridentata/Agropyron smithii* h.t.
      11. *Artemisia cana* dominant; *Artemisia tridentata* absent or very sparse .... *Artemisia cana/Agropyron smithii* h.t.
    10. *Artemisia tridentata* and *Artemisia cana* absent or inconspicuous.
        13. *Juniperus horizontalis* or *Rhus aromatica* well represented.
          14. *Juniperus horizontalis* dominant; *Rhus aromatica* absent or inconspicuous .... *Juniperus horizontalis/Carex heliophila* h.t.
          14. *Rhus aromatica* dominant; *Juniperus horizontalis* absent.
            15. *Carex filifolia* abundant; *Agropyron spicatum* and/or *Festuca idahoensis* absent .... *Rhus aromatica/Carex filifolia* h.t.
            15. *Agropyron spicatum* and/or *Festuca idahoensis* well represented; *Carex filifolia* absent or inconspicuous.
              16. *Agropyron spicatum* well represented; *Festuca idahoensis* absent .... *Rhus aromatica/Agropyron spicatum* h.t.
              16. *Festuca idahoensis* present and conspicuous; *Agropyron spicatum* also may be present .... *Rhus aromatica/Festuca idahoensis* h.t.
        13. *Juniperus horizontalis* and *Rhus aromatica* absent or inconspicuous.
              17. *Sarcobatus vermiculatus* or *Shepherdia argentea* abundant; *Symphoricarpos occidentalis* absent or not dominant.
                18. *Sarcobatus vermiculatus* dominant; *Shepherdia argentea* absent.
                  19. *Agropyron smithii* abundant; *Agropyron spicatum* absent .... *Sarcobatus vermiculatus/ Agropyron smithii* h.t.
                  19. *Agropyron spicatum* abundant; *Agropyron smithii* absent or inconspicuous .... *Sarcobatus vermiculatus/ Agropyron spicatum* h.t.
                18. *Shepherdia argentea* present; *Sarcobatus vermiculatus* absent .... *Shepherdia argentea* c.t.
              17. *Symphoricarpos occidentalis* abundant; *Sarcobatus vermiculatus* or *Shepherdia argentea* absent .... *Symphoricarpos occidentalis* c.t.

1. Tree species dominant; shrubs, graminoids, and forbs usually present.
   20. Coniferous tree species present and dominant; deciduous trees absent or rare.
      21. *Juniperus scopulorum* dominant and reproducing sufficiently; *Pinus ponderosa* may be present but is neither dominant nor reproducing sufficiently to maintain its population structure.
         22. *Agropyron spicatum* dominates undergrowth; *Oryzopsis micrantha* absent or inconspicuous . . . . *Juniperus scopulorum/Agropyron spicatum* h.t.
         22. *Oryzopsis micrantha* dominates undergrowth; *Agropyron spicatum* absent or rare . . . . *Juniperus scopulorum/Oryzopsis micrantha* h.t.
      21. *Pinus ponderosa* dominant and reproducing; *Juniperus scopulorum* may be present but not reproducing sufficiently to become dominant.
         23. Shrubs dominate the undergrowth; graminoids may be present but not dominant.
            24. *Prunus virginiana* well represented; *Juniperus communis* absent . . . . *Pinus ponderosa/Prunus virginiana* h.t.
            24. *Juniperus communis* present and dominant; *Prunus virginiana* also may be present but not dominant . . . . *Pinus ponderosa/Juniperus communis* h.t.
         23. Graminoids dominate the undergrowth; shrubs may be present but not abundant.
            25. *Carex heliophila* dominates undergrowth. *Agropyron spicatum* or *Festuca idahoensis* may be present but not abundant . . . . *Pinus ponderosa/Carex heliophila* h.t.
            25. *Carex heliophila* may be present but not abundant in undergrowth. *Agropyron spicatum* or *Festuca idahoensis* dominates undergrowth.
               26. *Agropyron spicatum* dominates undergrowth; *Festuca idahoensis* absent or rare . . . . *Pinus ponderosa/Agropyron spicatum* h.t.
               26. *Festuca idahoensis* dominates undergrowth; *Agropyron spicatum* absent or not abundant . . . . *Pinus ponderosa/Festuca idahoensis* h.t.
   20. Deciduous trees dominant and reproducing; coniferous trees absent or rare, not reproducing sufficiently.
               27. *Fraxinus pennsylvanica* dominant and reproducing; *Populus tremuloides* absent . . . . *Fraxinus pennsylvanica/Prunus virginiana* h.t.
               27. *Fraxinus pennsylvanica* absent or present in seedling and sapling size only; an occasional mature tree may be present; *Populus tremuloides* dominant and reproducing sufficiently to maintain its population structure . . . . *Populus tremuloides/Berberis repens* h.t.

Discussion

The Habitat Type Classification

Natural vegetation that develops over a long period of time without disturbance reflects the biotic potential of the landscape. Vegetation characteristics of natural vegetation, therefore, are convenient in developing an ecological classification of landscapes in which not only vegetation but also climate, soil, and disturbance factors are taken into account (Daubenmire 1976, Daubenmire and Daubenmire 1968).

A classification scheme provides a systematic ordering of the landscape units under study. In the present study, the units are the habitat types, and the method of defining and delimiting these provides as natural a classification as possible. The concept of habitat types is that landscapes can be categorized into units of similar biotic potential and that understanding succession and the indicator values of certain individual species is essential to this effort. Studies are being done to establish relationships between the basic habitat type concept and the applied values in resource management. Other studies have centered on productivity and grazing potentials (Mueggler and Stewart 1980), wildlife utilization (Hansen et al. 1984, Hironaka et al. 1983, Mackie 1970), small mammal distributions (Hoffman 1960, Rickard 1957), growth rates of trees (Daubenmire 1961, Rioux 1984), the role of fire in forest succession (Fischer and Clayton 1983), and silvicultural and watershed management implications (Hoffman and Alexander 1976, 1980, 1983, 1987). The use of habitat type maps is becoming an important management tool by providing a permanent record of habitat type distributions and a basis for total area estimates for land-use planning (Pfister et al. 1977; Steele et al. 1981, 1983).

The present classification and the key to identify the habitat types has been tested in the field.[4] The key was found to be useful and reliable. As with most keys written for habitat type identification, it works best in stands of older, relatively undisturbed vegetation. However, the key was developed to anticipate various degrees of disturbance. Where overgrazing has removed most of the palatable and, in some cases, dominant species, nearby less disturbed sites will have to be relied on for the presence of indicator species. In other cases, for example, *Rhus aromatica*-dominated habitat types, position of the landscape will have to be relied on to help separate the heavily grazed stands. In addition, the determination made can be verified by using the key to check the written descriptions of the habitat types.

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Species Richness

The median numbers of shrubs, graminoids, and forbs in the stands of each habitat type are given in table 2. Species richness generally is highest in the woodland- and steppe-dominated habitat types and lowest in the forest- and shrub-steppe-dominated habitat types. Among the steppe habitat types, species diversity ranged from a low of 13 in the *Agropyron smithii/Carex filifolia* habitat type to a high of 28 in the *Agropyron spicatum/C. filifolia* habitat type. In Theodore Roosevelt National Park of western North Dakota, the *A. smithii/C. filifolia* habitat type also showed the lowest species diversity of the steppe habitat types (Hansen et al. 1984). Species diversity among the shrub-steppe habitat types ranged from a low of 8 in the *Sarcobatus vermiculatus*-dominated habitat types to a high of 34 in the *Juniperus horizontalis/Carex heliophila* habitat type, which is the highest species diversity for the present study. Stands of the *J. horizontalis/C. heliophila* habitat type occupy relatively cool and mesic north-facing slopes. This is undoubtedly an important factor influencing species diversity in the semi-arid climate of the northern Great Plains. A similar *J. horizontalis/Andropogon scoparius* habitat type also had the highest species diversity in an earlier study in western North Dakota (Hansen et al. 1984). Species diversity among the woodland habitat types ranged from 21 in the *Juniperus scopulorum/Oryzopsis micrantha* habitat type to 26 in the *Populus tremuloides/Berberis repens* habitat type where wetter conditions probably account for more species. These numbers of species in woodland habitat types compare favorably with those of western North Dakota (Hansen et al. 1984). Among the forest habitat types, species diversity ranged from 10 in the *Pinus ponderosa/Carex heliophila* habitat type to 21 in the *P. ponderosa/Prunus virginiana* habitat type.

Species diversity among all habitat types ranged from a low of 8 in the two *Sarcobatus vermiculatus*-dominated habitat types to a high of 34 in the *Juniperus horizontalis/Carex heliophila* habitat type. The *J. horizontalis/C. heliophila* habitat type also had the highest forb diversity with 20. With the exception of the three graminoid-dominated forest habitat types, the woodland and forest habitat types generally had more shrubs than the steppe and shrub-steppe habitat types.

Table 2.—Species richness of undergrowth vegetation in the habitat types of the Custer National Forest.

Habitat type	Median number of undergrowth species[1]				Number of stands sampled
	Shrubs	Graminoids	Forbs	Total	
Steppe					
Stipa comata/Carex filifolia	1	9	15	25	18
Stipa comata/Carex heliophila	2	9	15	26	10
Festuca idahoensis/Carex heliophila	3	10	10	23	8
Agropyron smithii/Carex filifolia	1	9	3	13	10
Andropogon scoparius/Carex filifolia	2	7	9	18	16
Calamovilfa longifolia/Carex heliophila	1	7	8	16	4
Agropyron spicatum/Bouteloua curtipendula	3	8	15	26	3
Agropyron spicatum/Carex filifolia	2	11	15	28	2
Shrub-Steppe					
Artemisia tridentata/Agropyron spicatum	4	8	9	21	5
Artemisia tridentata/Agropyron smithii	2	6	7	15	7
Artemisia cana/Agropyron smithii	2	5	5	12	6
Juniperus horizontalis/Carex heliophila	5	9	20	34	7
Rhus aromatica/Agropyron spicatum	3	7	5	15	5
Rhus aromatica/Festuca idahoensis	3	10	8	21	2
Rhus aromatica/Carex filifolia	4	8	16	28	4
Sarcobatus vermiculatus/Agropyron spicatum	4	3	1	8	3
Sarcobatus vermiculatus/Agropyron smithii	1	5	2	8	2
Woodland					
Juniperus scopulorum/Agropyron spicatum	4	8	12	24	4
Juniperus scopulorum/Oryzopsis micrantha	6	6	9	21	3
Fraxinus pennsylvanica/Prunus virginiana	8	5	10	23	14
Populus tremuloides/Berberis repens	9	6	11	26	4
Forest					
Pinus ponderosa/Agropyron spicatum	2	7	9	18	3
Pinus ponderosa/Festuca idahoensis	1	6	11	18	2
Pinus ponderosa/Carex heliophila	1	5	4	10	3
Pinus ponderosa/Juniperus communis	5	5	2	12	2
Pinus ponderosa/Prunus virginiana	7	7	7	21	5

[1] *Based on fifty 0.1 m^2 microplots per stand.*

Management Implications

A habitat type classification provides a permanent and ecologically based system of land stratification in terms of vegetational potential (Daubenmire 1976). As the habitat type is the basic unit in classifying land units or sites based on their biotic potential, it emphasizes similarities and differences in ecosystems that carry implications for a variety of land management objectives (Daubenmire 1984). Habitat types provide a tool for categorizing research results, administrative study results, and accumulated field observations. The classification scheme also provides a basis for predicting the response of vegetation to management-related activities. Habitat types will complement information on existing vegetation, soils, outdoor recreation, hydrology, and wildlife, and will aid development of more intensive land-management planning and practices.

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Appendix 1. Tree Population Analysis

Tree population analyses of the Grand River, Sioux, and Ashland Districts. Population structure of trees in stands, by habitat types. Numbers of trees listed per 375 m^2, with basal area for the stands as m^2/ha. Districts are abbreviated as follows: G = Grand River/Cedar River, S = Sioux, A = Ashland. Abbreviations of tree species are as follows: Acne = *Acer negundo*, Frpe = *Fraxinus pennsylvanica*, Jusc = *Juniperus scopulorum*, Pipo = *Pinus ponderosa*, Potr = *Populus tremuloides*, Ulam = *Ulmus americana*.

Table A-1.—Population of trees by habitat type.

No. of stands	Mean basal area	Species	Diameter (at breast height) classes in dm							
			<0.5	>0.5-1	1-2	2-3	3-4	4-5	5-6	6-7
		Juniperus scopulorum/Agropyron spicatum habitat type								
4	18.7	Jusc	188	26	21	2			([1])	
		Juniperus scopulorum/Oryzopsis micrantha habitat type								
3	32.7	Jusc	195	45	31	7	1			
		Fraxinus pennsylvanica/Prunus virginiana habitat type								
14	29.1	Frpe	89	9	18	6	1	1	([1])	
		Acne	22	([1])	1	([1])	([1])			
		Ulam	([1])			([1])	([1])		([1])	
		Disturbed Stands								
		Fraxinus pennsylvanica/Prunus virginiana habitat type								
3	20.7	Frpe	12[2]		5	7	2	([1])		
		Acne	2[2]			1				
		Populus tremuloides/Berberis repens habitat type								
4	40.4	Potr	274	6	32	8	2			
		Frpe	148	7	2		([1])			
		Acne	7		([1])					
		Pipo	1	1						
		Pinus ponderosa/Agropyron spicatum habitat type								
3	33.6	Pipo	5	4	6	6	5		([1])	([1])
		Pinus ponderosa/Festuca idahoensis habitat type								
2	39.2	Pipo	118	9	10	7	4	([1])	([1])	([1])
		Pinus ponderosa/Carex heliophila habitat type								
3	52.3	Pipo	156	9	17	10	7	2	([1])	
		Jusc	3							
		Pinus ponderosa/Juniperus communis habitat type								
2	55.2	Pipo	242	10	22	12	2	([1])	([1])	([1])
		Pinus ponderosa/Prunus virginiana habitat type								
5	48.9	Pipo	391	9	17	9	3	2	1	([1])

[1] *Less than one tree per plot.*

[2] *Root suckers or stem-base suckers, rather than seedlings. All showed moderate to heavy browse damage.*

Appendix 2. Habitat Type and Community Type Tables with Stand Data

In the plant data, the number to the left of the slash is percent coverage where the value exceeds 0.5%; a + to the left of the slash indicates coverage of 0.5% or less. Number to the right of slash is percent frequency; species present in the macroplot but not in the microplots are indicated by *. Stand numbers, Ranger Districts, locations, and topographic positions also are given for each habitat type. Only the mean values of all plots are given for the community types. Districts are abbreviated as follows: Grand River/Cedar River District—G, Sioux District—S, Ashland District—A.

Table A-2.—*Stipa comata/Carex filifolia* habitat type.

Stand number	1	2	4	5	6	10	11	76	82	83	49	51	55	56	57	58	62	137
District	G	G	G	G	G	G	G	G	G	G	S	S	S	S	S	S	S	S
Location																		
Quarter section	NE	SW	SW	SW	NW	NE	SW	SE	NW	NE	NW	NE	SE	SE	NE	NW	NE	SW
Section	13	4	21	21	28	31	27	28	36	18	26	28	24	23	26	25	15	8
Township	21N	21N	22N	22N	22N	19N	22N	19N	18N	19N	2S	2S	21N	21N	21N	21N	22N	16N
Range	16E	14E	14E	14E	14E	13E	13E	13E	18E	18E	62E	62E	4E	4E	4E	4E	5E	4E
Topographic position																		
Slope (%)	2	--	--	2	4	13	8	4	13	12	5	3	--	2	1	3	2	--
Aspect (°)	243	--	--	258	128	98	345	263	38	298	127	77	--	62	357	347	297	--
Elevation (m)	--	--	--	--	--	--	--	--	--	--	1,006	1,036	1,030	1,036	1,036	1,033	994	1,167
									Coverage/Frequency									
Shrubs																		
Artemisia frigida	8/72	1/8	11/74	11/76	14/72	13/72	4/38	5/42	4/60	--	1/8	+/4	3/32	3/26	2/28	2/18	4/28	6/60
Gutierrezia sarothrae	--	--	1/2	--	+/2	--	--	--	--	--	--	--	+/2	--	--	--	--	--
Opuntia fragilis	*	--	--	--	--	+/2	*	+/2	+/2	+/2	+/2	*	--	--	--	--	--	--
Opuntia polyacantha	--	--	--	--	--	--	--	--	--	--	--	--	--	--	+/2	--	--	--
Rosa arkansana	--	--	--	--	--	--	--	1/8	--	--	--	--	--	1/12	--	--	*	--
Yucca glauca	--	--	*	--	*	*	--	--	--	--	--	--	--	--	--	--	--	--
Graminoids																		
Agropyron cristatum	1/28	*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Agropyron dasystachyum	--	--	20/50	13/58	25/88	--	--	--	--	--	--	--	--	--	--	--	--	--
Agropyron smithii	3/30	27/90	22/60	13/58	11/34	7/40	4/24	6/50	--	49/99	11/98	10/82	1/18	+/12	3/36	19/80	4/52	6/56
Agropyron spicatum	--	--	--	2/6	+/2	--	--	--	--	--	--	--	--	--	--	--	--	--
Aristida longiseta	+/8	+/2	--	--	--	2/18	*	4/28	+/4	6/28	3/30	2/18	+/4	3/12	1/26	+/2	1/14	+/2
Bouteloua curtipendula	--	--	--	--	--	--	--	2/10	--	--	--	--	--	--	--	--	--	--
Bouteloua gracilis	8/38	31/64	1/6	1/10	1/4	3/22	11/58	2/16	30/94	4/12	9/86	5/52	1/22	4/28	2/18	5/56	1/26	3/16
Bromus japonicus	--	20/74	--	--	--	--	--	--	--	+/6	+/4	+/10	--	--	--	--	+/4	+/8
Calamovilfa longifolia	+/2	--	--	--	--	--	--	1/10	2/4	+/2	--	--	--	--	--	--	--	--
Carex brevior	1/2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Carex eleocharis	--	5/74	12/64	3/34	6/48	11/64	*	1/20	+/2	+/2	3/58	+/8	+/12	*	*	1/14	1/40	+/2
Carex filifolia	8/30	32/99	76/99	87/99	84/99	73/99	67/99	71/99	55/99	59/99	63/99	32/99	41/99	23/99	29/99	50/90	59/99	64/99
Carex heliophila	--	--	--	--	--	--	--	--	5/30	+/4	+/2	+/8	1/4	*	*	18/34	+/8	--
Festuca octoflora	+/2	10/52	--	--	--	--	--	+/2	+/14	8/62	+/6	--	--	--	--	--	+/2	--
Koeleria pyramidata	6/30	*	--	--	1/8	+/4	9/42	1/12	23/98	5/52	2/10	7/68	5/58	*	1/24	3/32	8/62	6/54
Muhlenbergia cuspidata	--	--	--	1/6	+/2	--	--	--	--	--	--	--	--	--	--	--	--	--
Panicum wilcoxianum	3/34	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Poa pratensis	--	2/20	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Poa sandbergii	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	+/2
Schedonnardus paniculatus	1/6	+/4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Stipa comata	84/99	85/99	48/96	74/99	75/99	73/99	72/99	77/99	71/99	74/99	88/99	81/99	78/99	77/99	81/99	77/99	84/99	78/99
Stipa viridula	--	2/8	3/22	+/4	1/12	--	--	--	--	9/44	--	--	--	--	--	+/6	--	--
Forbs																		
Achillea millefolium	--	1/4	--	--	--	--	--	--	--	--	--	*	*	--	+/4	--	--	--
Allium textile	*	--	*	+/2	--	--	+/6	*	+/6	--	--	--	--	--	--	--	--	--
Ambrosia psilostachya	--	+/4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Antennaria rosea	*	*	--	--	--	--	--	--	--	--	--	+/2	--	+/2	--	--	--	--
Artemisia campestris	--	--	--	--	+/2	--	*	--	--	--	--	--	--	--	--	--	*	--
Artemisia dracunculus	2/34	7/40	4/28	4/50	2/18	+/4	4/38	3/28	--	--	--	--	3/12	2/28	*	*	+/4	1/10
Artemisia ludoviciana	--	+/2	--	+/2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Asclepias pumila	--	--	--	--	--	--	--	+/6	--	--	--	--	--	--	--	--	--	--
Aster brachyactis	--	--	--	--	--	--	--	--	--	--	+/8	+/2	+/10	+/6	+/4	*	+/12	--
Aster ericoides	2/24	--	--	--	+/2	--	1/6	1/8	--	--	--	+/6	2/14	1/4	--	+/2	*	--

Aster brachyactis	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Astragalus crassicarpus	--	--	--	+ /6	--	--	[illegible]	--	--	+ /2	--	--	--	--	--	--	--	--
Calylophus serrulatus	*	--	--	--	--	--	+ /2	--	--	--	--	--	--	--	--	--	--	--
Cerastium arvense	--	--	--	--	--	--	--	--	--	1/14	--	--	--	--	--	--	--	--
Chenopodium album	--	--	--	--	--	+ /2	--	--	--	--	--	--	--	--	--	--	--	--
Chenopodium dessicatum	--	+ /14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chrysopsis villosa	+ /10	--	*	1/10	+ /6	--	+ /2	+ /6	1/14	--	--	--	2/10	5/36	1/6	*	4/26	*
Cirsium undulatum	--	--	--	--	--	--	+ /2	+ /2	+ /2	--	--	*	*	*	--	--	--	--
Collomia linearis	--	--	+ /12	*	--	--	--	--	--	--	--	--	+ /26	*	1/22	--	--	--
Comandra umbellata	--	+ /6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	+ /6	--
Coryphantha missouriensis	--	--	--	--	--	--	--	+ /2	--	--	--	--	--	--	--	--	--	--
Echinacea angustifolia	+ /8	--	*	*	*	*	--	*	+ /2	--	--	--	--	1/10	--	--	1/14	--
Erysimum asperum	--	--	+ /2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gaura coccinea	+ /6	+ /2	+ /4	+ /2	+ /4	1/12	+ /2	+ /6	+ /2	+ /4	--	1/12	3/34	1/12	+ /6	+ /18	--	*
Haplopappus spinulosus	--	--	--	--	--	--	--	--	+ /4	--	--	--	--	--	--	--	--	--
Hedeoma hispida	+ /2	1/30	--	--	--	--	+ /12	+ /24	+ /2	1/24	1/24	--	--	--	--	--	--	+ /2
Helianthus annuus	--	+ /6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Helianthus rigidus	--	--	--	--	--	+ /2	--	--	--	--	--	--	--	--	--	--	--	--
Hymenopappus filifolius	*	--	--	--	--	--	*	--	--	--	--	--	--	--	--	--	--	--
Hymenoxys acaulis	--	--	*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lactuca oblongifolia	--	--	--	--	--	--	--	--	--	+ /4	--	--	--	--	--	--	--	--
Liatris punctata	+ /4	*	*	2/16	1/12	+ /6	--	+ /2	+ /4	--	+ /2	+ /2	--	+ /4	--	--	+ /6	--
Linum perenne	+ /4	--	--	--	--	--	*	--	*	--	--	--	+ /4	--	--	--	--	--
Linum rigidum	--	--	--	--	--	--	+ /2	--	--	2/30	--	--	--	--	--	--	--	--
Lithospermum incisum	+ /6	--	--	*	--	--	--	*	--	--	--	--	+ /2	+ /6	+ /2	--	+ /4	--
Lotus purshianus	1/20	+ /6	--	--	--	--	--	+ /6	1/56	1/12	--	--	2/34	5/66	5/74	22/99	+ /6	--
Lygodesmia juncea	+ /8	1/10	1/8	--	--	1/22	+ /6	1/4	--	--	+ /2	1/20	1/14	+ /10	--	+ /20	1/26	1/20
Melilotus officinalis	--	+ /6	--	--	--	*	+ /2	--	--	--	--	--	--	--	--	--	--	--
Orobanche fasciculata	--	--	*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Orthocarpus luteus	--	*	--	--	--	--	--	--	--	--	+ /6	+ /8	1/22	+ /2	+ /2	--	+ /2	--
Oxytropis lambertii	2/18	--	--	--	--	--	*	--	1/10	--	--	+ /2	+ /4	+ /2	+ /4	--	*	--
Penstemon albidus	--	--	--	--	--	--	--	+ /2	+ /4	--	--	--	--	--	--	--	--	--
Penstemon angustifolius	--	--	--	--	--	--	+ /6	--	--	--	--	--	--	--	--	--	--	--
Penstemon gracilis	+ /4	--	--	--	--	--	--	--	--	--	--	+ /4	--	--	--	--	--	--
Petalostemon purpureum	1/34	--	--	--	--	--	2/10	1/10	2/20	--	2/18	3/22	+ /6	1/14	--	--	+ /2	+ /2
Phlox andicola	--	--	--	--	--	--	--	--	--	--	+ /4	--	--	+ /8	--	--	--	--
Phlox hoodii	--	--	--	--	--	--	--	+ /2	--	--	--	--	--	--	--	--	--	--
Plantago patagonica	+ /2	1/24	--	--	--	--	+ /8	+ /4	+ /2	+ /4	--	--	+ /2	--	--	--	--	--
Polygala alba	--	--	--	--	--	--	+ /4	--	--	--	--	--	--	--	--	--	--	--
Polygala verticillata	--	--	--	--	--	--	--	--	--	--	1/50	--	--	--	1/32	--	--	--
Potentilla arguta	--	--	--	--	--	--	--	--	--	--	+ /4	*	--	--	--	--	--	--
Potentilla pensylvanica	*	--	--	--	--	*	+ /2	+ /2	--	1/4	--	--	--	--	--	--	--	--
Psoralea argophylla	*	*	--	--	--	*	1/10	1/16	--	+ /2	+ /2	1/28	+ /6	+ /8	1/8	1/16	+ /6	--
Psoralea esculenta	--	--	--	*	+ /4	--	*	*	--	--	--	--	--	*	--	--	+ /2	--
Psoralea tenuiflora	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	+ /2
Ratibida columnifera	2/16	+ /4	--	--	--	*	+ /2	*	*	+ /2	--	--	--	+ /2	+ /2	*	--	--
Selaginella densa	--	--	--	--	--	--	--	--	--	--	3/16	32/88	27/96	16/86	9/80	4/44	13/99	21/92
Solidago graminifolia	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	+ /2	--	--
Solidago missouriensis	--	--	--	--	--	--	--	--	4/20	--	+ /6	+ /2	+ /4	--	--	--	--	--
Sphaeralcea coccinea	+ /6	--	2/44	1/38	2/50	1/22	--	3/38	--	5/46	+ /6	*	+ /4	+ /2	+ /4	1/18	+ /4	*
Taraxacum officinale	--	--	--	--	--	--	+ /2	--	--	--	--	--	--	--	--	--	--	--
Thermopsis rhombifolia	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	+ /6	--
Tragopogon dubius	--	+ /2	+ /2	*	*	+ /2	--	--	--	--	+ /2	+ /6	+ /2	+ /4	--	+ /2	--	--
Vicia americana	--	+ /2	--	--	1/6	--	--	--	--	--	--	--	--	--	--	--	--	--
Bare ground	18/99	1/10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Species in microplots	31	28	16	18	22	17	26	31	25	25	26	24	29	27	22	19	27	16
Coverage of shrubs	8	1	12	11	14	13	4	6	4	0	1	0	3	4	2	2	4	6
Coverage of graminoids	114	214	182	194	204	169	163	165	186	214	179	137	127	107	117	173	158	157
Coverage of forbs	11	11	7	8	7	3	9	10	9	11	7	38	41	32	18	28	19	23
Total coverage	133	226	201	213	225	185	176	181	199	225	187	175	171	143	137	203	181	186

Table A-3.—*Stipa comata/Carex heliophila* habitat type.

Stand number	63	112	113	116	118	29	38	40	102	108
District	S	S	S	S	S	A	A	A	A	A
Location										
Quarter section	SW	SW	SW	SE	NW	SE	SE	NE	SW	NW
Section	25	3	33	28	25	1	18	17	14	3
Township	1N	2S	1S	1N	1N	5S	6S	6S	3S	6S
Range	58E	61E	61E	58E	58E	44E	45E	45E	45E	44E
Topographic position										
Slope (%)	2	2	4	8	--	3	2	2	8	5
Aspect (°)	327	317	217	222	--	220	110	255	175	180
Elevation (m)	1,219	1,219	1,225	1,244	1,207	1,253	1,253	1,244	981	1,247
					Coverage/Frequency					
Shrubs										
Artemisia cana	--	--	--	--	--	+/2	+/4	--	--	--
Artemisia frigida	1/12	1/16	1/12	1/20	+/8	*	5/56	2/18	--	2/24
Gutierrezia sarothrae	--	--	--	--	--	+/2	3/22	1/12	--	+/4
Opuntia fragilis	+/2	--	--	--	--	--	--	--	--	--
Rosa arkansana	+/2	*	+/4	1/32	3/50	1/14	+/8	+/2	--	--
Symphoricarpos occidentalis	--	*	--	--	--	--	--	--	--	--
Graminoids										
Agropyron smithii	4/72	8/68	7/82	1/22	2/44	25/70	2/20	1/18	1/36	2/44
Agropyron spicatum	--	--	--	--	--	--	10/58	9/32	--	--
Aristida longiseta	--	--	--	--	--	--	+/2	1/6	1/8	--
Bouteloua curtipendula	--	--	--	--	--	1/4	--	+/2	+/2	--
Bouteloua gracilis	18/96	*	--	+/2	1/14	--	1/12	6/28	7/34	+/2
Bromus japonicus	--	--	--	--	--	23/76	+/10	3/50	2/44	30/99
Calamovilfa longifolia	--	--	--	--	--	+/4	--	--	--	--
Carex eleocharis	1/14	--	--	+/4	--	--	--	+/4	--	--
Carex filifolia	3/14	--	1/4	2/6	+/2	--	--	--	--	--
Carex heliophila	67/99	68/99	70/99	39/99	61/99	50/99	23/99	26/99	26/72	52/99
Festuca idahoensis	--	--	--	--	--	--	--	1/4	--	2/4
Festuca octoflora	+/2	+/2	--	--	--	--	--	--	+/18	--
Koeleria pyramidata	1/18	5/58	6/62	4/82	3/58	2/28	8/76	10/84	6/66	5/36
Muhlenbergia cuspidata	--	--	--	--	--	--	1/2	3/16	--	--
Poa canbyi	--	2/12	+/6	--	--	7/38	--	--	--	6/56
Poa pratensis	--	9/32	--	--	+/2	--	1/6	--	--	--
Poa sandbergii	--	--	--	+/4	--	--	--	--	--	--
Stipa comata	57/99	57/99	81/99	82/99	83/99	48/90	41/99	40/96	74/99	50/99
Stipa viridula	1/8	27/82	1/4	--	+/2	16/48	1/8	3/36	1/6	4/32
Forbs										
Achillea millefolium	+/2	+/4	+/2	--	+/2	*	+/16	+/4	--	1/6
Ambrosia psilostachya	--	--	--	--	--	2/24	--	+/10	--	--
Antennaria rosea	+/2	+/2	+/2	2/16	1/2	3/16	1/8	+/6	+/2	*
Artemisia campestris	3/18	--	--	--	--	--	--	--	--	--
Artemisia dracunculus	+/4	--	+/2	--	+/2	*	1/4	--	4/34	*
Artemisia ludoviciana	6/48	6/66	6/48	1/84	11/92	2/38	1/30	3/56	13/58	3/36
Asclepias verticillata	--	--	--	--	--	--	--	--	+/8	--
Asclepias viridiflora	--	--	--	--	--	*	--	--	--	--
Aster brachyactis	+/20	--	--	--	--	--	--	--	--	--
Aster ericoides	2/20	+/10	*	*	4/60	7/60	+/10	2/30	1/6	+/8
Calylophus serrulatus	*	--	--	--	--	--	--	--	--	--
Cerastium arvense	--	1/18	--	1/6	--	--	--	--	--	--
Chrysopsis villosa	2/18	*	+/2	2/30	3/24	1/4	1/14	--	+/4	--
Cirsium undulatum	*	--	--	--	--	--	--	--	--	--
Collomia linearis	+/16	--	--	--	--	--	--	--	--	+/20
Coryphantha vivipara	--	--	--	--	--	--	--	--	--	+/2
Echinacea angustifolia	1/26	+/2	+/2	--	+/10	--	1/14	+/2	+/2	+/4
Erysimum asperum	--	--	--	--	--	--	--	+/2	--	--
Gaura coccinea	+/2	+/20	+/6	--	+/2	+/12	+/6	+/2	+/4	+/8
Geum triflorum	--	--	--	--	--	*	--	--	--	--
Hedeoma hispida	--	--	--	+/2	--	--	--	--	--	--
Helianthus rigidus	--	+/8	--	--	+/2	--	--	--	--	--
Kuhnia eupatorioides	--	--	--	--	--	--	--	+/2	--	--
Lactuca oblongifolia	+/8	--	+/2	--	--	--	--	--	--	--
Liatris punctata	1/6	*	*	+/6	1/14	--	*	--	--	+/2
Linum rigidum	--	--	--	--	--	--	*	--	--	--

Lithospermum incisum	--	--	+ /2	--	--	--	--	+ /2	--	--
Lupinus argenteus	--	1/6	--	--	--	--	--	--	--	*
Lygodesmia juncea	+ /2	--	+ /2	--	--	+ /2	--	--	+ /4	+ /10
Orthocarpus luteus	+ /4	*	+ /6	1/28	1/26	1/16	--	*	--	+ /18
Oxytropis lambertii	+ /2	--	+ /2	+ /2	1/8	--	--	--	--	--
Penstemon angustifolius	--	--	--	--	--	--	+ /6	--	--	--
Penstemon gracilis	--	--	+ /2	--	1/8	--	*	--	--	--
Petalostemon purpureum	+ /4	--	+ /2	+ /6	+ /6	+ /2	+ /4	+ /12	--	--
Phlox andicola	--	--	--	--	--	--	1/18	1/16	--	+ /6
Phlox hoodii	--	--	--	--	+ /6	--	--	--	--	--
Plantago patagonica	--	--	--	--	--	--	--	--	*	*
Potentilla arguta	*	--	--	--	--	--	--	--	--	--
Psoralea argophylla	+ /4	+ /8	+ /4	+ /4	*	+ /10	1/38	+ /12	+ /6	*
Psoralea esculenta	--	--	--	--	--	--	+ /2	--	+ /4	--
Ratibida columnifera	--	--	*	*	--	1/16	+ /8	+ /2	1/22	+ /8
Selaginella densa	1/8	3/26	41/88	68/99	49/96	--	--	--	3/22	--
Solidago rigida	--	+ /6	+ /4	--	--	--	--	--	+ /2	--
Sphaeralcea coccinea	+ /10	--	+ /2	--	+ /4	--	+ /2	+ /8	--	+ /12
Tragopogon dubius	--	1/12	*	--	--	+ /2	--	--	*	*
Vicia americana	+ /4	--	--	--	--	--	--	--	--	--
Zigadenus venenosus	--	+ /4	--	--	--	--	--	--	--	--
Species in microplots	33	23	27	21	27	24	30	31	24	24
Coverage of shrubs	1	1	1	2	3	1	8	3	0	2
Coverage of graminoids	152	176	166	128	150	172	88	103	118	151
Coverage of forbs	16	12	47	84	72	17	7	6	22	4
Total coverage	169	189	214	214	225	190	103	112	140	157

Table A-4.—*Festuca idahoensis/Carex heliophila* habitat type.

Stand number	**26**	**41**	**42**	**43**	**86**	**106**	**107**	**109**
District	A	A	A	A	A	A	A	A
Location								
Quarter section	SE	NE	SW	SW	SE	SE	NE	SW
Section	34	17	9	14	36	5	3	15
Township	6S	6S	6S	6S	6S	6S	6S	6S
Range	47E	45E	45E	44E	43E	44E	44E	44E
Topographic position								
Slope (%)	5	5	5	15	12	7	5	--
Aspect (°)	180	5	205	20	355	245	125	--
Elevation (m)	1,262	1,237	1,271	1,250	1,183	1,244	1,247	1,256
				Coverage/Frequency				
Shrubs								
Artemisia cana	1/4	--	--	--	--	--	--	--
Artemisia frigida	--	1/8	+ /4	1/14	+ /6	+ /4	*	+ /2
Gutierrezia sarothrae	--	+ /10	+ /4	+ /2	+ /2	1/8	*	--
Rhus aromatica	--	--	--	--	*	--	--	--
Rosa arkansana	2/12	--	2/16	1/38	--	+ /6	+ /12	+ /18
Symphoricarpos occidentalis	--	--	--	--	1/12	--	--	--
Graminoids								
Agropyron smithii	6/42	1/12	9/72	2/70	+ /10	+ /12	2/24	2/22
Agropyron spicatum	--	+ /4	--	--	+ /2	+ /2	+ /2	--
Andropogon gerardi	--	1/8	1/2	--	--	--	--	--
Aristida longiseta	--	--	1/16	1/18	+ /4	--	*	--
Bouteloua curtipendula	--	+ /4	--	--	1/10	--	1/10	--
Bouteloua gracilis	6/28	--	3/24	--	--	3/8	1/6	2/28
Bromus japonicus	+ /4	--	1/20	+ /2	1/10	--	+ /2	+ /12
Calamovilfa longifolia	7/38	--	--	--	--	--	--	--
Carex heliophila	39/99	27/99	17/96	56/99	34/99	13/84	9/92	10/92
Festuca idahoensis	67/98	65/98	50/99	87/99	83/99	81/99	82/99	87/99
Festuca octoflora	+ /2	--	--	--	--	--	--	--
Koeleria pyramidata	12/66	3/28	3/38	+ /14	8/64	3/44	1/38	2/34
Muhlenbergia cuspidata	--	1/12	--	--	--	--	--	--

Poa canbyi	--	--	--	--	4/34	--	--	--
Poa sandbergii	6/28	--	--	--	--	--	*	--
Stipa comata	11/54	1/6	6/44	1/6	*	+/6	1/20	1/16
Stipa viridula	+/2	1/22	+/2	1/8	+/2	--	--	+/2
Forbs								
Achillea millefolium	--	+/16	*	+/8	*	*	--	*
Ambrosia psilostachya	1/8	--	1/12	--	+/10	--	+/10	--
Antennaria rosea	--	+/2	+/2	--	1/4	1/14	+/2	+/2
Artemisia dracunculus	--	--	--	*	--	*	1/8	--
Artemisia ludoviciana	6/48	3/46	+/10	7/64	2/28	+/2	1/26	3/60
Aster ericoides	1/4	4/50	8/64	7/50	1/4	1/10	+/4	1/10
Astragalus adsurgens	--	--	--	--	--	--	*	--
Cerastium arvense	--	--	--	--	+/8	--	--	--
Chrysopsis villosa	--	--	+/2	+/6	--	--	*	--
Cirsium undulatum	+/2	+/2	+/6	+/4	--	--	--	--
Echinacea angustifolia	--	1/22	1/12	+/4	2/26	*	+/6	*
Erysimum asperum	--	--	+/4	--	--	--	--	--
Gaura coccinea	+/6	+/4	--	+/10	--	+/2	+/2	--
Geum triflorum	--	4/30	--	+/2	*	--	--	--
Kuhnia eupatorioides	--	--	*	--	--	--	--	--
Liatris punctata	--	*	--	+/2	--	+/2	*	--
Linum perenne	--	*	--	--	--	--	--	--
Lithospermum incisum	--	--	--	--	--	+/2	--	+/2
Lupinus argenteus	*	+/2	+/2	2/18	1/4	*	1/8	*
Lygodesmia juncea	*	--	--	--	--	--	--	1/6
Orthocarpus luteus	+/8	+/4	--	+/10	--	--	--	--
Oxytropis sericea	--	+/2	--	--	--	--	--	--
Petalostemon purpureum	--	2/30	4/40	1/16	--	--	*	--
Phlox alyssifolia	--	+/4	--	--	--	--	--	--
Phlox andicola	--	2/22	+/2	--	--	+/2	+/10	--
Phlox hoodii	--	--	--	--	1/18	--	--	--
Potentilla arguta	--	--	--	+/2	--	--	--	--
Psoralea argophylla	--	+/8	--	1/18	1/14	--	--	+/2
Psoralea esculenta	--	--	+/18	--	--	--	*	+/2
Ratibida columnifera	*	1/26	*	+/10	*	--	*	--
Solidago graminifolia	--	--	--	1/16	--	--	--	--
Solidago missouriensis	1/14	--	+/4	+/6	--	--	--	--
Solidago rigida	+/2	--	--	--	--	--	--	+/4
Sphaeralcea coccinea	--	--	--	*	--	1/22	+/20	1/40
Tragopogon dubius	--	--	+/2	+/6	--	--	--	*
Vicia americana	--	--	--	--	+/4	--	--	--
Zigadenus venenosus	--	--	--	+/8	--	--	*	--
Bare ground	--	--	--	--	--	20/99	17/98	11/99
Species in microplots	21	28	27	30	23	18	20	19
Coverage of shrubs	3	1	2	2	1	1	0	0
Coverage of graminoids	154	100	91	148	131	100	97	104
Coverage of forbs	9	17	14	19	9	3	3	6
Total coverage	166	118	107	169	141	104	100	110

Table A-5.—*Agropyron smithii/Carex filifolia* habitat type.

Stand number	**3**	**8**	**16**	**65**	**73**	**81**	**52**	**61**	**136**	**138**
District	G	G	G	G	G	G	S	S	S	S
Location										
Quarter section	SW	SE	NW	SW	SW	NE	NE	NE	NW	SE
Section	3	14	3	5	5	26	28	26	2	8
Township	21N	20N	19N	20N	19N	18N	2S	21N	21N	16N
Range	14E	15E	13E	16E	13E	18E	62E	4E	5E	4E
Topographic position										
Slope (%)	--	8	--	6	2	--	7	--	2	--
Aspect (°)	--	168	--	170	13	--	177	--	307	--
Elevation (m)	--	--	--	--	--	--	1,033	1,093	1,018	1,164

	Coverage/Frequency									
Shrubs										
Artemisia cana	--	3/8	--	--	--	--	--	--	--	--
Artemisia frigida	--	--	--	4/28	+ /4	--	+ /6	--	--	5/70
Opuntia fragilis	--	--	+ /4	+ /2	--	--	+ /4	--	--	--
Opuntia polyacantha	--	+ /2	--	--	--	--	--	--	--	+ /4
Symphoricarpos occidentalis	--	1/6	--	--	--	--	--	--	--	--
Graminoids										
Agropyron smithii	88/99	92/99	77/99	66/99	98/99	90/99	76/99	96/99	91/99	79/99
Alopecurus carolinianus	12/70	--	--	--	--	12/84	--	--	--	--
Andropogon scoparius	--	+ /2	--	--	--	--	--	--	--	--
Aristida longiseta	--	--	+ /2	1/4	--	--	+ /2	--	--	+ /2
Bouteloua curtipendula	--	*	2/8	--	--	--	--	--	--	--
Bouteloua gracilis	--	5/16	15/32	8/62	--	--	12/86	--	--	1/4
Bromus japonicus	--	--	*	--	2/38	--	+ /2	--	--	23/99
Buchloe dactyloides	--	--	31/48	4/12	--	+ /2	--	--	--	--
Calamovilfa longifolia	--	--	--	1/4	--	--	--	--	--	--
Carex eleocharis	--	3/16	13/74	1/24	37/98	--	--	--	--	*
Carex filifolia	--	70/99	*	48/99	11/46	--	--	--	--	63/99
Carex heliophila	--	--	--	--	--	--	4/24	+ /6	--	--
Distichlis spicata	--	--	--	--	--	--	2/36	--	--	--
Eleocharis acicularis	--	--	--	--	--	--	--	38/98	28/99	--
Festuca octoflora	--	--	2/34	+ /4	2/32	--	--	--	--	--
Hordeum jubatum	--	--	--	--	--	--	--	--	5/32	--
Juncus interior	--	--	--	--	--	--	+ /6	--	--	--
Koeleria pyramidata	--	+ /6	*	5/40	--	--	+ /2	--	--	1/22
Poa pratensis	--	1/8	--	--	+ /4	--	+ /4	--	--	4/12
Poa sandbergii	--	--	--	--	--	--	--	--	--	4/32
Schedonnardus paniculatus	--	--	+ /2	--	--	--	--	--	--	--
Stipa comata	--	4/38	2/10	5/38	1/4	--	--	--	--	6/38
Stipa viridula	--	12/48	+ /2	13/64	+ /4	--	--	--	--	8/24
Forbs										
Achillea millefolium	--	--	--	--	+ /2	--	--	--	--	+ /8
Allium textile	--	--	*	+ /4	--	--	--	--	--	--
Anemone patens	--	+ /2	--	--	--	--	--	--	--	--
Antennaria rosea	--	--	--	*	--	--	--	--	--	--
Artemisia dracunculus	--	--	*	+ /2	--	--	--	--	--	*
Aster brachyactis	--	--	--	+ /8	--	--	+ /6	--	--	--
Astragalus crassicarpus	--	--	--	+ /2	--	--	--	--	--	--
Cerastium brachypodum	--	--	--	+ /10	--	--	--	--	--	--
Collomia linearis	--	--	--	+ /4	--	--	--	--	--	--
Coryphantha missouriensis	--	--	--	--	--	--	*	--	--	--
Echinacea angustifolia	--	--	--	*	--	--	--	--	--	--
Gaura coccinea	--	*	--	*	--	--	--	--	--	+ /2
Grindelia squarrosa	*	--	*	--	--	--	--	--	--	--
Hedeoma hispida	--	--	--	1/46	+ /2	--	+ /8	--	--	--
Helianthus rigidus	--	+ /2	--	--	--	--	--	--	--	--
Lithospermum incisum	--	--	--	--	--	--	--	--	--	+ /2
Lotus purshianus	--	--	+ /6	3/64	--	--	--	--	--	--
Lygodesmia juncea	--	+ /2	--	--	--	--	--	--	--	+ /6
Melilotus officinalis	--	--	--	1/2	--	--	--	--	--	--
Orthocarpus luteus	--	--	--	--	--	--	*	--	--	--
Penstemon gracilis	--	--	--	1/10	--	--	--	--	--	--
Plagiobothrys scouleri	--	--	--	--	--	38/84	--	--	--	--
Plantago patagonica	--	--	4/52	+ /8	--	--	--	--	--	--
Polygala alba	--	--	--	+ /2	--	--	--	--	--	--
Polygala verticillata	--	--	--	--	--	--	1/16	--	--	--
Polygonum ramosissimum	9/48	--	2/12	--	--	4/48	--	--	--	--
Potentilla arguta	--	--	--	--	--	--	+ /2	--	--	--
Potentilla glandulosa	--	--	--	--	--	--	--	--	--	+ /2
Psoralea argophylla	--	--	--	1/4	--	--	--	--	--	+ /10
Psoralea esculenta	--	+ /2	--	*	--	--	--	--	--	--
Ratibida columnifera	--	--	--	1/16	--	--	--	--	--	--
Selaginella densa	--	--	--	--	--	--	55/88	--	--	13/86
Sphaeralcea coccinea	--	1/10	1/18	6/64	--	--	--	--	--	--
Tragopogon dubius	--	*	--	+ /2	*	--	--	--	--	--
Vicia americana	--	--	+ /8	--	--	--	--	--	--	--
Species in microplots	3	17	16	29	11	5	16	3	3	19
Coverage of shrubs	0	4	0	4	0	0	0	0	0	5
Coverage of graminoids	100	187	142	152	151	102	94	134	124	189
Coverage of forbs	9	1	7	14	0	42	56	0	0	13
Total coverage	109	192	149	170	151	144	150	134	124	207

Table A-6.—*Andropogon scoparius/Carex filifolia* habitat type.

Stand number	12	13	14	17	64	67	71	77	122	127	139	141	19	20	21	22
District	G	G	G	G	G	G	G	G	S	S	S	S	A	A	A	A
Location																
Quarter section	SW	SE	SE	NE	SW	SE	NE	SE	NE	NE	NE	SW	NE	NE	NW	NW
Section	27	14	14	4	18	6	8	31	11	26	19	19	21	21	19	19
Township	22N	20N	20N	19N	20N	20N	23N	19N	2S	19N	19N	19N	4S	4S	6S	6S
Range	13E	15E	15E	13E	16E	16E	11E	13E	60E	7E	8E	8E	45E	45E	46E	46E
Topographic position																
Slope (%)	18	18	8	15	8	12	5	17	30	30	25	20	35	36	15	12
Aspect (°)	308	348	308	333	223	293	193	38	37	337	22	282	45	320	355	5
Elevation (m)	--	--	--	--	--	--	--	--	1,055	1,061	1,061	1,079	969	969	1,012	1,012
								Coverage/Frequency								
Shrubs																
Artemisia cana	--	*	--	--	--	--	--	--	--	+/2	--	--	--	--	--	--
Artemisia frigida	+/6	+/8	1/16	+/10	+/10	+/8	+/4	1/8	+/2	*	+/4	*	+/4	2/20	1/12	1/8
Artemisia tridentata	--	--	--	--	--	--	--	--	--	--	--	--	+/2	--	--	--
Gutierrezia sarothrae	*	--	+/4	--	+/2	--	--	--	--	--	--	--	+/2	1/16	1/16	+/6
Opuntia fragilis	--	--	*	--	--	--	--	--	--	--	--	--	--	--	--	--
Opuntia polyacantha	--	--	--	--	--	--	--	--	--	--	--	--	+/2	--	*	--
Rhus aromatica	--	--	--	--	--	--	--	--	*	3/8	*	--	*	+/2	--	--
Rosa arkansana	+/8	1/22	1/8	*	--	+/8	+/2	+/8	1/46	2/18	+/2	+/8	+/6	--	--	*
Shepherdia argentea	--	+/4	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Symphoricarpos occidentalis	--	--	--	+/2	--	--	--	+/2	--	2/12	--	--	--	--	--	--
Toxicodendron rydbergii	--	+/2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Yucca glauca	--	--	--	*	--	*	--	--	+/2	--	*	--	+/2	--	--	+/4
Graminoids																
Agropyron caninum	--	+/4	--	--	--	--	1/22	--	--	--	--	--	--	--	--	--
Agropyron dasystachyum	--	--	--	--	--	--	--	--	--	--	+/2	--	--	--	--	--
Agropyron smithii	--	--	--	1/10	+/4	--	--	+/10	--	--	--	--	--	--	--	--
Agropyron spicatum	--	--	--	--	--	--	--	--	--	--	--	--	9/56	6/18	+/4	3/12
Andropogon scoparius	78/99	67/99	58/99	69/99	79/99	86/99	88/99	86/99	84/99	97/99	91/99	97/99	55/98	41/90	70/99	68/99
Aristida longiseta	--	--	--	--	--	--	--	--	--	--	--	--	1/4	1/4	--	--
Bouteloua curtipendula	--	9/64	28/98	2/4	2/38	5/18	--	*	--	--	--	--	11/68	17/84	6/40	5/48
Bouteloua gracilis	--	--	+/2	--	2/16	1/6	--	--	--	--	+/2	--	--	--	--	--
Bromus japonicus	--	--	--	--	--	--	--	--	--	--	--	--	--	+/2	+/4	+/4
Calamovilfa longifolia	4/22	6/32	3/18	12/54	1/6	--	+/4	1/22	--	--	1/12	*	--	--	--	--
Carex eleocharis	--	--	+/6	--	--	--	--	+/2	--	--	--	--	--	--	--	--
Carex filifolia	52/99	39/99	40/99	47/99	37/99	49/99	17/78	22/88	22/92	21/84	24/86	12/70	1/10	27/96	18/82	21/86
Carex heliophila	--	--	--	--	--	--	--	9/46	4/36	--	5/28	6/60	6/34	1/24	2/18	+/4
Festuca idahoensis	--	--	--	--	--	--	--	--	--	--	--	--	--	1/6	--	--
Festuca octoflora	--	--	--	--	*	+/4	--	--	--	--	--	--	--	--	--	--
Helictotrichon hookeri	--	--	--	--	--	--	--	--	--	--	+/2	--	--	--	--	--
Koeleria pyramidata	2/32	4/44	2/28	1/18	1/34	1/18	1/12	2/18	3/52	--	+/2	*	2/32	2/34	+/6	1/8
Muhlenbergia cuspidata	--	--	--	--	--	--	--	--	--	--	+/4	--	--	1/4	--	--
Poa canbyi	--	--	--	--	--	--	--	--	+/6	--	--	--	--	--	--	--
Poa pratensis	--	+/2	--	1/4	--	+/2	--	*	--	*	+/2	--	--	--	--	--
Poa sandbergii	--	--	--	--	--	--	--	--	--	--	*	--	--	--	--	--
Stipa comata	+/6	1/10	+/2	--	*	--	--	--	*	--	+/2	--	+/2	+/2	+/4	+/2
Stipa viridula	--	+/6	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Forbs																
Achillea millefolium	--	--	--	--	--	--	*	--	--	+/6	+/10	+/2	1/26	--	--	--
Agoseris glauca	--	--	--	--	--	--	+/2	--	--	--	--	--	--	--	--	--
Allium textile	+/2	+/6	--	--	*	--	--	+/6	--	--	--	--	--	+/2	--	--
Anemone canadensis	--	--	--	--	--	--	--	+/8	--	+/6	--	--	--	--	--	--
Anemone cylindrica	1/6	--	--	+/2	--	--	--	--	--	--	--	+/4	--	--	--	--
Anemone patens	5/52	6/70	--	--	--	--	--	--	--	+/6	--	1/32	--	--	--	--
Antennaria rosea	--	--	+/6	+/6	--	--	+/2	--	+/6	*	--	--	+/12	+/12	+/2	+/4
Arabis hirsuta	--	--	--	--	--	--	1/42	+/8	--	--	--	--	--	--	--	--
Artemisia campestris	1/16	--	--	--	*	+/10	--	+/6	+/2	--	--	--	--	--	--	--
Artemisia dracunculus	*	1/18	+/10	+/6	+/4	1/10	--	*	+/2	+/2	*	*	--	--	--	--

Artemisia campestris	[illegible]	1/18	+ /10	+ /6	+ /4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Artemisia dracunculus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	+ /2	--	[illegible]	+ /4	+ /2	--	+ /10	--	--	+ /2
Asclepias pumila	--	--	--	--	--	--	--	--	--	--	--	--	+ /6	--	--	--
Aster brachyactis	--	--	--	--	--	--	•	--	--	--	--	--	--	--	--	--
Aster ericoides	--	--	1/12	+ /8	1/24	+ /10	+ /6	+ /10	•	+ /4	1/32	+ /4	1/20	1/22	1/18	+ /4
Astragalus adsurgens	--	+ /2	--	+ /4	--	--	6/32	•	--	--	--	--	--	--	--	--
Astragalus flexuosus	•	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Astragalus gilviflorus	--	+ /4	--	+ /2	+ /4	•	+ /2	+ /4	--	+ /2	--	--	--	+ /4	--	--
Astragalus gracilis	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2/26	+ /4
Astragalus spatulatus	--	--	--	--	--	--	--	--	--	--	--	--	--	+ /2	--	--
Calylophus serrulatus	+ /2	2/22	--	+ /2	+ /6	--	--	+ /2	--	•	--	--	+ /4	+ /2	--	--
Campanula rotundifolia	--	--	--	--	--	--	--	--	--	--	+ /8	+ /10	+ /6	2/22	--	--
Castilleja sessiliflora	--	--	--	+ /6	--	--	1/4	--	--	--	--	--	+ /2	+ /2	--	--
Cerastium arvense	--	--	--	--	--	--	--	--	1/38	--	--	+ /2	--	--	--	--
Cerastium nutans	--	--	--	--	--	--	+ /8	--	--	--	--	--	--	--	--	--
Chrysopsis villosa	2/20	+ /6	•	--	--	1/6	•	•	+ /10	--	+ /4	•	+ /4	•	--	--
Cirsium undulatum	•	--	--	•	--	--	+ /2	+ /10	--	--	--	--	--	--	•	--
Comandra umbellata	2/20	3/56	--	--	+ /2	--	1/18	•	1/34	•	+ /10	+ /10	--	--	--	--
Coryphantha missouriensis	--	--	•	--	--	--	--	--	--	--	--	--	--	--	--	--
Echinacea angustifolia	1/26	6/60	2/34	1/22	+ /6	2/50	1/20	+ /18	1/48	--	--	--	2/50	8/86	2/36	3/34
Erysimum cheiranthoides	--	--	--	--	--	--	•	+ /2	--	--	--	--	--	--	--	--
Galium boreale	--	--	--	--	--	--	--	--	--	--	2/36	--	--	--	--	--
Gaura coccinea	--	--	•	1/6	+ /2	+ /6	+ /2	•	--	+ /2	--	--	--	--	--	--
Geum triflorum	--	--	--	--	--	--	--	--	--	+ /2	•	--	--	--	•	--
Glycyrrhiza lepidota	--	3/34	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hedeoma hispida	--	--	--	--	+ /2	+ /4	--	--	--	--	--	--	--	--	--	--
Helianthus rigidus	•	2/32	--	1/20	--	•	1/8	4/42	•	+ /2	3/42	1/14	--	--	--	--
Hymenopappus filifolius	+ /2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hymenoxys acaulis	•	+ /2	+ /2	+ /2	--	+ /2	--	--	--	--	--	--	--	--	--	--
Lactuca oblongifolia	--	--	--	1/26	--	+ /10	+ /2	+ /6	--	--	--	--	--	--	--	--
Liatrus punctata	+ /10	+ /2	+ /4	--	+ /2	+ /6	--	--	1/32	--	--	--	+ /2	1/12	+ /2	+ /4
Linum perenne	--	+ /2	--	--	--	--	--	--	--	--	+ /2	--	+ /2	+ /2	--	--
Linum rigidum	--	--	+ /6	+ /2	+ /2	•	+ /2	--	--	--	--	+ /2	+ /2	+ /2	--	+ /2
Lithospermum incisum	--	--	--	1/4	--	--	--	--	--	--	--	--	--	--	--	--
Lotus purshianus	--	--	--	--	--	+ /2	--	--	--	--	--	--	--	--	--	--
Lygodesmia juncea	--	--	1/14	•	1/28	+ /8	+ /4	+ /2	+ /4	--	--	--	--	--	+ /10	+ /4
Melilotus officinalis	•	+ /2	--	--	--	•	--	--	--	--	--	--	--	--	+ /2	+ /2
Monarda fistulosa	--	--	--	--	--	--	--	--	--	1/26	--	--	--	--	--	--
Mosses and lichens	1/16	--	--	--	--	11/99	--	--	--	--	--	--	--	--	--	--
Orthocarpus luteus	--	--	+ /2	--	--	--	--	--	•	--	--	--	--	•	2/14	--
Oxytropis lambertii	2/14	1/8	1/18	+ /8	+ /6	+ /6	+ /2	--	+ /2	--	--	--	2/20	+ /8	+ /4	2/16
Oxytropis sericea	--	--	--	--	+ /2	--	--	--	--	--	--	--	--	--	--	--
Penstemon gracilis	--	--	--	•	--	--	--	--	--	--	--	--	--	--	--	--
Petalostemon candidum	--	1/8	--	+ /2	--	--	--	--	--	--	--	--	--	--	--	--
Petalostemon occidentale	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	•
Petalostemon purpureum	5/44	3/46	+ /6	+ /2	1/38	1/24	•	+ /2	4/54	--	1/12	1/26	+ /4	1/12	+ /6	+ /2
Phlox alyssifolia	--	--	--	--	--	--	+ /6	--	--	--	--	--	--	--	--	--
Phlox hoodii	--	--	--	--	+ /18	+ /8	--	+ /4	--	--	--	--	+ /8	1/18	•	--
Polygala alba	+ /2	--	--	+ /2	+ /2	+ /8	+ /2	--	--	--	--	--	+ /4	+ /2	+ /2	--
Potentilla arguta	--	+ /6	--	--	--	--	--	--	--	+ /2	--	--	--	--	--	--
Potentilla pensylvanica	--	--	--	•	--	--	--	--	--	--	--	--	--	--	--	--
Psoralea argophylla	--	--	+ /8	+ /2	•	1/18	3/52	1/26	--	--	+ /2	--	+ /10	+ /2	1/22	1/18
Psoralea esculenta	•	--	•	--	+ /2	+ /2	+ /2	•	•	--	+ /4	1/4	•	+ /2	+ /2	--
Psoralea tenuiflora	--	--	--	--	--	--	--	--	--	--	--	•	--	--	--	--
Ratibida columnifera	+ /2	--	--	•	--	•	--	•	--	--	--	--	+ /4	--	--	--
Selaginella densa	--	--	--	--	--	--	+ /10	--	3/32	--	+ /2	--	--	--	--	--
Senecio canus	--	--	--	--	--	--	--	--	--	--	+ /2	--	--	•	--	--
Senecio plattensis	•	--	+ /2	--	--	--	--	--	--	--	--	--	--	--	--	--
Solidago missouriensis	--	--	+ /2	--	+ /10	+ /2	--	--	--	--	2/4	--	1/18	+ /2	--	--
Solidago nemoralis	•	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Solidago rigida	--	4/44	+ /4	1/10	--	--	--	+ /8	+ /2	+ /2	1/12	+ /6	+ /4	--	--	--
Sphaeralcea coccinea	--	--	+ /2	--	•	+ /2	--	--	--	--	--	--	--	--	--	--
Taraxacum officinale	--	--	--	--	--	--	+ /4	--	--	--	--	--	--	--	--	--
Thermopsis rhombifolia	--	--	--	--	--	--	--	--	--	--	1/12	--	--	•	--	--
Thlaspi arvense	--	--	--	--	--	--	--	--	--	--	--	--	+ /2	--	--	--
Tragopogon dubius	•	--	--	--	--	--	--	--	--	--	--	--	•	--	•	+ /4
Vicia americana	--	--	+ /2	--	--	--	--	--	--	--	--	--	--	--	--	--
Species in microplots	22	33	28	30	27	30	31	27	21	19	30	16	36	33	23	24
Coverage of shrubs	0	1	2	0	0	0	0	1	1	7	0	0	0	3	2	1
Coverage of graminoids	136	126	131	133	122	142	107	120	113	118	121	115	85	97	96	98
Coverage of forbs	20	32	5	6	3	17	14	5	11	1	11	4	7	14	8	6
Total coverage	156	159	138	139	125	159	121	126	125	126	132	119	92	114	106	105

Table A-7.—*Calamovilfa longifolia/Carex heliophila* habitat type.

Stand number	148	149	150	151
District	G	G	G	G
Location				
Quarter section	SW	NW	NE	NW
Section	17	35	22	22
Township	22N	23N	20N	20N
Range	11E	12E	15E	15E
Topographic position				
Slope (%)	10	15	15	5
Aspect (°)	158	128	348	168
Elevation (m)	--	--	--	--
		Coverage/Frequency		
Shrubs				
Artemisia frigida	--	+/2	+/2	1/4
Graminoids				
Agropyron smithii	1/24	*	--	1/12
Andropogon gerardi	*	--	--	--
Aristida longiseta	--	1/8	--	--
Bouteloua gracilis	+/6	4/42	+/2	1/4
Bromus japonicus	--	--	--	1/18
Calamovilfa longifolia	93/99	94/99	95/99	96/99
Carex filifolia	1/2	1/8	--	--
Carex heliophila	90/99	91/99	91/99	64/98
Festuca octoflora	--	--	+/2	+/8
Koeleria pyramidata	+/6	+/12	+/6	+/2
Poa pratensis	--	+/6	2/4	+/2
Stipa comata	+/2	--	--	--
Stipa viridula	*	--	--	--
Forbs				
Ambrosia psilostachya	--	--	2/12	4/40
Artemisia dracunculus	--	1/6	*	--
Artemisia ludoviciana	6/46	+/16	*	2/16
Aster ericoides	--	--	--	*
Chenopodium album	--	--	+/6	+/4
Conyza canadensis	--	+/4	*	+/8
Gaura coccinea	--	+/2	--	--
Glycyrrhiza lepidota	+/4	--	--	--
Hedeoma hispida	--	--	+/4	+/8
Lactuca oblongifolia	1/26	--	--	--
Liatris punctata	--	--	+/2	--
Lithospermum incisum	--	--	+/2	--
Lotus purshianus	--	+/8	--	--
Lygodesmia juncea	+/4	--	2/20	+/2
Psoralea argophylla	2/24	2/56	*	+/2
Ratibida columnifera	--	+/8	--	--
Solidago rigida	+/6	--	2/10	--
Sphaeralcea coccinea	--	--	--	+/4
Tragopogon dubius	--	--	+/2	--
Species in microplots	13	15	15	17
Coverage of shrubs	0	0	0	1
Coverage of graminoids	185	191	188	163
Coverage of forbs	9	3	6	6
Total coverage	194	194	194	170

Table A-8.—*Agropyron spicatum/Bouteloua curtipendula* and *Agropyron spicatum/Carex filifolia* habitat types.

	Agropyron/Bouteloua			*Agropyron/Carex*	
Stand number	**23**	**24**	**25**	**30**	**31**
District	A	A	A	A	A
Location					
Quarter section	SW	NW	SE	SW	SW
Section	36	4	31	6	6
Township	4S	5S	6S	5S	5S
Range	45E	47E	47E	45E	45E
Topographic position					
Slope (%)	25	37	55	4	2
Aspect (°)	155	180	90	5	35
Elevation (m)	985	1,146	1,158	1,253	1,256
			Coverage/Frequency		
Shrubs					
Artemisia cana	--	+ /2	--	--	--
Artemisia frigida	--	1/4	+ /4	6/30	2/22
Gutierrezia sarothrae	1/6	--	2/34	1/16	1/10
Opuntia polyacantha	*	*	--	--	+ /2
Rhus aromatica	--	2/4	6/14	--	--
Yucca glauca	*	*	--	--	--
Graminoids					
Agropyron smithii	--	8/44	18/94	+ /8	1/6
Agropyron spicatum	42/98	46/96	61/99	58/94	58/99
Andropogon gerardi	--	3/8	--	--	--
Andropogon scoparius	16/72	2/12	--	--	--
Aristida longiseta	*	--	--	--	--
Bouteloua curtipendula	13/70	11/66	4/16	--	--
Bouteloua gracilis	--	--	--	1/10	1/6
Bromus japonicus	+ /4	--	2/36	12/44	13/70
Bromus tectorum	+ /4	--	+ /2	2/4	+ /2
Calamovilfa longifolia	--	+ /2	--	--	--
Carex eleocharis	--	--	--	+ /4	+ /4
Carex filifolia	4/20	1/4	--	7/32	22/78
Carex heliophila	--	--	--	6/18	--
Danthonia spicata	--	--	--	+ /2	--
Koeleria pyramidata	*	*	--	8/66	6/70
Muhlenbergia cuspidata	3/24	+ /2	+ /2	--	--
Poa canbyi	--	--	--	1/8	7/58
Sitanion hystrix	*	+ /2	--	--	--
Stipa comata	1/2	1/4	--	5/46	3/24
Stipa viridula	--	+ /4	1/18	--	--
Forbs					
Achillea millefolium	--	--	--	2/28	+ /2
Ambrosia psilostachya	+ /6	+ /6	1/14	4/56	12/94
Antennaria rosea	+ /2	--	--	+ /8	2/12
Artemisia ludoviciana	2/20	+ /2	--	--	*
Asclepias pumila	+ /6	--	--	--	--
Aster ericoides	+ /2	+ /2	+ /6	5/42	8/62
Astragalus gilviflorus	--	+ /6	--	--	--
Astragalus gracilis	+ /6	--	--	--	--
Cerastium arvense	--	--	--	--	1/20
Chrysopsis villosa	1/6	--	--	*	--
Cirsium undulatum	*	--	--	+ /4	1/12
Echinacea angustifolia	2/24	+ /10	--	2/12	+ /2
Gaura coccinea	--	+ /6	+ /10	+ /2	+ /16
Grindelia squarrosa	--	9/68	*	--	--
Helianthus rigidus	--	+ /2	--	--	--
Kuhnia eupatorioides	+ /2	--	--	*	--
Liatris punctata	*	*	--	*	--
Linum perenne	--	--	--	*	--
Lithospermum canescens	--	+ /8	--	--	--
Lithospermum incisum	--	--	--	--	+ /2
Lygodesmia juncea	+ /2	1/14	+ /2	--	--
Orthocarpus luteus	--	--	--	+ /6	1/26

Stand number	Agropyron/Bouteloua 23	24	25	Agropyron/Carex 30	31
Oxytropis sericea	--	--	--	--	*
Penstemon albidus	+/2	--	--	--	--
Penstemon angustifolius	--	--	*	--	--
Penstemon gracilis	--	+/4	*	*	--
Petalostemon candidum	--	2/20	--	--	--
Petalostemon occidentale	--	*	--	--	--
Petalostemon purpureum	1/16	--	--	3/18	+/2
Phacelia hastata	--	--	*	--	--
Phlox alyssifolia	--	--	--	+/8	1/14
Phlox hoodii	1/8	+/2	--	--	--
Polygala alba	--	--	--	*	2/16
Psoralea argophylla	1/22	--	+/4	1/22	1/24
Psoralea esculenta	+/2	*	--	--	--
Psoralea tenuiflora	--	--	--	+/12	--
Ratibida columnifera	--	+/2	*	+/4	+/4
Sphaeralcea coccinea	--	+/10	2/50	--	--
Tragopogon dubius	*	--	+/8	+/4	--
Vicia americana	--	--	+/6	--	--
Bare ground	--	40/99	26/98	--	--
Species in microplots	24	29	18	28	28
Coverage of shrubs	1	3	8	7	3
Coverage of graminoids	79	72	86	100	111
Coverage of forbs	8	12	3	17	29
Total coverage	88	87	97	124	143

Table A-9.—*Artemisia tridentata/Agropyron spicatum* habitat type.

Stand number	18	96	97	98	104
District	A	A	A	A	A
Location					
Quarter section	NW	SE	NW	NW	NE
Section	4	25	22	22	22
Township	5S	6S	5S	5S	6S
Range	46E	45E	44E	44E	43E
Topographic position					
Slope (%)	9	8	55	20	70
Aspect (°)	220	55	215	160	185
Elevation (m)	1,024	1,018	1,061	1,055	1,122
			Coverage/Frequency		
Shrubs					
Artemisia cana	+/2	--	--	+/2	--
Artemisia frigida	+/4	+/2	--	1/14	+/2
Artemisia tridentata	17/56	22/68	28/72	18/56	21/60
Atriplex confertifolia	--	--	--	--	*
Gutierrezia sarothrae	7/44	2/30	+/2	3/30	+/2
Opuntia fragilis	--	--	--	*	--
Opuntia polyacantha	*	*	--	*	*
Rhus aromatica	1/8	--	--	--	+/4
Rosa arkansana	1/6	--	1/12	--	--
Symphoricarpos occidentalis	+/4	--	--	--	--
Yucca glauca	2/2	--	+/2	--	--
Graminoids					
Agropyron smithii	9/32	+/8	6/40	1/20	--
Agropyron spicatum	45/88	45/99	37/96	47/96	27/84
Aristida longiseta	*	--	+/2	+/2	--
Bouteloua curtipendula	11/40	--	--	6/16	--
Bouteloua gracilis	1/4	1/2	--	1/4	--
Bromus japonicus	--	+/8	1/14	14/88	*
Bromus tectorum	--	*	--	--	1/4
Carex heliophila	--	--	--	+/2	--
Festuca idahoensis	*	--	--	--	--

Koeleria pyramidata	4/40	13/84	2/22	5/24	--
Oryzopsis hymenoides	--	--	--	--	4/10
Poa canbyi	--	1/8	1/8	1/18	--
Poa pratensis	1/2	--	--	1/6	--
Stipa comata	1/8	1/2	--	1/4	--
Stipa viridula	1/8	+ /4	1/8	13/36	--
Forbs					
Achillea millefolium	*	--	1/4	1/20	--
Allium textile	--	+ /2	*	*	--
Aster ericoides	--	--	--	+ /4	--
Astragalus gilviflorus	*	--	--	--	--
Camelina microcarpa	--	3/78	+ /4	2/54	--
Ceratoides lanata	2/12	3/18	--	+ /2	--
Comandra umbellata	+ /2	--	1/10	*	--
Echinacea angustifolia	+ /6	--	--	*	--
Eriogonum pauciflorum	--	--	+ /2	--	--
Gaura coccinea	+ /2	--	--	--	--
Grindelia squarrosa	+ /2	--	--	--	--
Hedemona hispida	--	--	--	--	+ /6
Linum perenne	+ /6	--	+ /2	4/38	--
Linum rigidum	--	+ /2	--	--	--
Penstemon gracilis	*	--	--	--	--
Petalostemon candidum	*	--	--	--	--
Phacelia hastata	--	--	--	--	+ /2
Phlox andicola	--	1/22	+ /2	+ /2	--
Phlox hoodii	+ /18	--	--	--	--
Psoralea argophylla	+ /8	--	--	--	--
Psoralea esculenta	--	*	--	+ /4	--
Ratibida columnifera	+ /2	--	--	--	--
Senecio canus	+ /6	--	--	--	--
Sphaeralcea coccinea	1/22	+ /2	+ /2	+ /12	+ /10
Thermopsis rhombifolia	--	--	2/18	--	--
Tragopogon dubius	1/18	*	--	+ /10	*
Vicia americana	*	--	+ /16	*	+ /6
Bare ground	--	26/94	44/99	14/99	--
Species in microplots	28	17	20	25	11
Coverage of shrubs	28	24	29	22	21
Coverage of graminoids	73	61	48	90	32
Coverage of forbs	4	7	4	7	0
Total coverage	105	92	81	119	53

Table A-10.—*Artemisia tridentata/Agropyron smithii* habitat type.

Stand number	**59**	**121**	**124**	**32**	**34**	**35**	**105**
District	S	S	S	A	A	A	A
Location							
Quarter section	SE	NE	NE	NW	NW	NW	NW
Section	26	11	19	22	9	9	4
Township	1S	2S	2S	4S	7S	7S	7S
Range	60E	60E	61E	44E	47E	47E	44E
Topographic position							
Slope (%)	2	8	5	5	3	3	10
Aspect (°)	232	317	107	20	275	275	195
Elevation (m)	1,039	1,039	1,061	986	1,219	1,219	1,219
				Coverage/Frequency			
Shrubs							
Artemisia cana	--	--	--	2/6	--	--	--
Artemisia frigida	*	1/8	+ /4	2/8	*	1/6	*
Artemisia tridentata	29/86	25/96	33/92	19/54	14/42	21/56	26/72
Gutierrezia sarothrae	+ /2	--	+ /2	3/22	2/18	3/22	1/10
Opuntia fragilis	--	+ /2	--	--	--	+ /2	+ /6
Opuntia polyacantha	3/24	2/28	1/14	*	*	*	--

Stand number	59	121	124	32	34	35	105
Graminoids							
Agropyron dasystachyum	+ /2	--	*	--	+ /2	+ /2	--
Agropyron smithii	23/96	69/99	67/99	32/94	43/99	21/99	21/94
Agropyron spicatum	--	--	--	11/40	--	--	--
Aristida longiseta	--	--	--	+ /4	--	--	--
Bouteloua gracilis	3/12	4/20	2/14	7/32	--	+ /2	+ /6
Bromus japonicus	--	1/40	+ /8	11/52	13/88	10/88	5/90
Carex filifolia	--	--	--	3/20	--	--	--
Festuca idahoensis	--	--	--	--	--	*	--
Festuca octoflora	--	--	+ /2	--	--	--	--
Koeleria pyramidata	+ /6	1/12	1/8	3/30	21/86	18/68	19/96
Poa canbyi	--	4/40	5/48	5/38	3/18	6/20	19/80
Schedonnardus paniculatus	1/6	--	--	--	--	+ /4	--
Stipa comata	+ /4	--	--	2/8	--	--	--
Stipa spartea	--	--	--	--	--	+ /2	--
Stipa viridula	+ /6	--	*	8/48	6/40	22/78	11/54
Forbs							
Achillea millefolium	--	--	--	1/14	1/20	1/22	2/58
Antennaria rosea	--	--	--	--	3/16	+ /4	--
Aster ericoides	--	--	--	1/8	--	+ /2	--
Calochortus nuttallii	--	--	--	+ /4	--	--	--
Camelina microcarpa	--	+ /2	--	2/40	+ /18	+ /14	10/98
Cerastium arvense	--	--	--	--	1/8	--	--
Ceratoides lanata	--	--	--	--	--	4/38	--
Collomia linearis	--	--	--	--	--	--	+ /2
Comandra umbellata	--	--	--	2/28	--	+ /4	--
Echinacea angustifolia	--	--	--	+ /2	--	--	--
Erigeron pumilus	--	--	--	+ /2	--	--	--
Gaura coccinea	--	--	--	*	--	--	--
Hedeoma hispida	--	--	+ /4	--	--	--	--
Linum perenne	--	--	--	2/20	--	--	--
Lygodesmia juncea	--	--	--	*	--	--	--
Mosses and lichens	--	--	--	--	1/18	+ /4	--
Orthocarpus luteus	--	--	--	+ /2	+ /4	+ /2	--
Penstemon gracilis	--	--	--	+ /2	--	--	--
Phlox alyssifolia	--	--	--	1/12	+ /8	+ /10	--
Phlox andicola	+ /8	--	--	--	--	--	5/70
Plantago patagonica	*	--	--	--	--	--	--
Psoralea argophylla	--	--	--	+ /10	--	--	--
Psoralea esculenta	--	--	--	*	--	+ /2	--
Ratibida columnifera	--	--	--	1/10	--	--	--
Selaginella densa	10/54	25/64	4/14	--	--	--	--
Sphaeralcea coccinea	--	--	+ /2	+ /2	+ /8	+ /4	+ /20
Taraxacum officinale	--	--	--	--	--	2/20	--
Tragopogon dubius	--	--	*	+ /2	1/22	+ /6	--
Vicia americana	--	--	--	+ /4	1/28	1/10	2/42
Bare ground	--	23/99	27/99	--	12/78	8/68	--
Species in microplots	12	11	13	30	18	27	15
Coverage of shrubs	32	28	34	26	16	25	27
Coverage of graminoids	27	79	75	82	86	77	75
Coverage of forbs	10	25	4	10	8	8	19
Total coverage	69	132	113	118	110	110	121

Table A-11.—*Artemisia cana/Agropyron smithii* habitat type.

Stand number	60	125	129	37	91	103
District	S	S	S	A	A	A
Location						
Quarter section	SE	NE	SW	NW	SE	SW
Section	26	29	12	25	17	18
Township	1S	2S	2S	6S	5S	3S
Range	60E	61E	60E	45E	43E	46E
Topographic position						
Slope (%)	2	8	5	2	--	2
Aspect (°)	232	357	217	130	--	125
Elevation (m)	1,030	1,088	1,049	1,036	957	951
			Coverage/Frequency			
Shrubs						
Artemisia cana	58/98	35/90	28/58	25/78	34/58	26/74
Artemisia frigida	--	--	--	1/16	+ /2	+ /2
Gutierrezia sarothrae	--	--	--	+ /8	--	--
Opuntia fragilis	--	--	--	+ /2	--	--
Rosa woodsii	--	--	--	--	--	+ /2
Symphoricarpos occidentalis	*	3/28	--	--	--	1/2
Graminoids						
Agropyron smithii	76/98	77/99	83/99	32/99	77/99	84/99
Aristida longiseta	--	--	--	*	--	--
Bouteloua curtipendula	--	--	30/72	--	--	--
Bouteloua gracilis	--	3/20	+ /2	40/90	--	--
Bromus japonicus	--	--	--	10/90	1/20	3/20
Buchloe dactyloides	15/30	--	20/34	--	--	--
Festuca octoflora	--	--	--	+ /8	--	--
Koeleria pyramidata	--	1/30	8/70	4/24	--	--
Poa compressa	--	--	--	1/10	--	--
Poa pratensis	25/62	11/42	2/20	2/4	11/34	73/99
Poa sandbergii	--	--	--	3/22	--	--
Stipa comata	--	--	+ /8	+ /10	--	--
Stipa viridula	5/32	6/58	10/54	7/28	2/24	3/22
Forbs						
Achillea millefolium	2/40	+ /10	1/16	+ /2	1/2	13/62
Allium textile	--	--	+ /2	--	--	--
Antennaria rosea	--	--	+ /2	--	--	--
Artemisia dracunculus	1/4	--	--	--	--	--
Artemisia ludoviciana	--	--	--	--	2/10	--
Aster ericoides	+ /4	+ /2	+ /4	--	--	--
Calochortus nuttallii	--	--	+ /4	*	--	--
Camelina microcarpa	--	--	--	2/32	--	--
Ceratoides lanata	--	--	--	*	--	--
Cirsium undulatum	--	--	--	*	--	--
Echinacea angustifolia	--	--	*	--	--	--
Gaura coccinea	--	--	--	+ /2	--	--
Lactuca oblongifolia	--	--	--	--	--	2/8
Linum rigidum	--	--	+ /4	+ /8	--	--
Melilotus officinalis	+ /2	--	--	--	--	--
Penstemon angustifolius	--	--	--	+ /2	--	--
Penstemon gracilis	--	--	--	*	--	--
Phlox alyssifolia	--	--	1/6	--	--	--
Phlox andicola	--	--	--	+ /8	--	--
Psoralea argophylla	--	+ /4	--	+ /2	--	--
Ratibida columnifera	+ /4	--	+ /2	*	--	*
Taraxacum officinale	2/32	--	--	1/22	4/30	--
Tragopogon dubius	--	--	+ /2	+ /4	--	*
Vicia americana	+ /4	--	+ /20	--	--	+ /2
Bare ground	--	--	--	16/99	--	--
Species in microplots	12	10	19	23	9	11
Coverage of shrubs	58	38	28	26	34	27
Coverage of graminoids	121	98	153	99	91	163
Coverage of forbs	5	0	2	3	7	15
Total coverage	184	136	183	128	132	205

Table A-12.—*Juniperus horizontalis/Carex heliophila* habitat type.

Stand number	44	45	46	48	130	140	144
District	S	S	S	S	S	S	S
Location							
Quarter section	SW	SW	NE	NE	SE	SE	SE
Section	25	25	25	25	10	24	13
Township	19N	19N	19N	19N	1S	19N	17N
Range	7E	7E	7E	7E	61E	7E	7E
Topographic position							
Slope (%)	50	52	45	45	35	80	60
Aspect (°)	7	4	17	10	27	357	17
Elevation (m)	1,073	1,073	1,076	1,073	1,079	1,067	1,085
				Coverage/Frequency			
Shrubs							
Artemisia frigida	1/22	1/20	+/6	+/6	+/6	+/16	+/4
Gutierrezia sarothrae	+/6	+/6	--	+/10	+/4	+/8	--
Juniperus communis	--	--	--	--	--	3/8	*
Juniperus horizontalis	76/99	87/99	71/94	56/70	90/99	95/99	98/99
Opuntia polyacantha	+/2	--	--	+/4	--	--	--
Prunus virginiana	--	--	1/16	--	--	+/8	*
Rhus aromatica	+/2	--	+/4	2/6	--	--	+/2
Ribes cereum	--	--	--	--	--	--	+/6
Ribes missouriense	--	--	--	--	--	+/2	--
Rosa arkansana	+/8	--	1/26	--	+/4	+/6	--
Symphoricarpos occidentalis	+/4	+/2	1/18	+/8	--	4/46	1/22
Toxicodendron rydbergii	--	--	--	--	--	+/6	--
Graminoids							
Agropyron caninum	--	--	+/2	--	+/4	--	--
Agropyron dasystachyum	1/6	9/56	+/4	1/14	--	20/86	11/68
Agropyron spicatum	--	--	--	--	13/66	--	--
Andropogon scoparius	5/20	1/4	41/92	46/99	1/10	1/6	+/2
Bouteloua curtipendula	--	--	--	1/4	--	--	--
Calamovilfa longifolia	9/30	2/4	2/18	1/6	3/16	--	--
Carex filifolia	6/42	8/30	3/24	3/20	4/14	4/30	6/36
Carex heliophila	22/74	33/96	17/90	3/52	33/99	19/64	16/74
Festuca ovina	--	--	--	--	--	--	+/12
Helictotrichon hookeri	+/2	+/2	+/14	+/10	--	--	--
Koeleria pyramidata	4/38	1/20	+/2	1/14	+/10	+/6	1/14
Muhlenbergia cuspidata	1/8	1/6	1/14	+/10	--	2/12	*
Poa arida	2/26	--	1/8	+/6	--	--	--
Poa pratensis	--	--	--	--	--	+/4	--
Poa sandbergii	--	--	--	--	--	--	*
Stipa comata	2/22	+/8	+/8	1/4	1/12	--	*
Forbs							
Achillea millefolium	1/12	+/16	+/12	+/6	*	+/8	+/6
Allium textile	--	--	--	--	+/4	--	--
Anemone cylindrica	--	+/2	+/10	+/2	+/2	+/6	--
Anemone patens	2/50	3/68	2/42	2/54	--	+/6	1/26
Antennaria rosea	--	--	--	--	--	+/2	--
Artemisia campestris	--	+/6	+/2	--	--	--	--
Artemisia dracunculus	--	--	+/2	--	+/2	--	--
Aster ericoides	--	*	+/2	+/2	1/18	--	--
Astragalus adsurgens	+/2	1/8	+/2	+/2	--	--	*
Campanula rotundifolia	1/36	1/34	1/24	1/22	+/6	+/6	1/40
Cerastium arvense	--	--	--	--	+/2	+/4	*
Chrysopsis villosa	+/2	+/2	*	--	--	--	--
Comandra umbellata	--	+/10	+/8	1/30	+/4	*	--
Echinacea angustifolia	--	--	--	+/4	--	--	--
Erigonum flavum	--	+/4	--	--	--	--	--
Galium boreale	+/6	+/4	1/24	1/24	--	2/44	1/26
Geum triflorum	+/4	1/4	--	--	+/2	+/4	+/2
Helianthus rigidus	--	--	--	1/10	--	--	--
Heuchera richardsonii	--	+/4	+/4	+/2	+/2	--	+/2
Hymenoxys acaulis	+/2	+/10	+/2	+/10	--	--	--
Linum perenne	*	--	+/2	--	--	+/4	--
Linum rigidum	--	--	--	--	*	--	--
Lupinus argenteus	1/2	--	+/2	+/4	1/10	*	*

Microseris cuspidata	--	--	--	--	--	+ /4	+ /2
Monarda fistulosa	--	--	+ /4	--	--	+ /8	--
Oxytropis lambertii	--	--	--	--	+ /2	--	--
Oxytropis sericea	2/20	1/16	--	--	*	+ /4	+ /6
Petalostemon purpureum	1/16	+ /8	4/60	2/22	+ /2	+ /2	--
Phlox alyssifolia	+ /8	--	--	2/24	--	--	--
Psoralea esculenta	+ /2	+ /2	--	--	*	--	*
Selaginella densa	3/12	1/8	+ /4	1/6	1/6	--	--
Senecio canus	+ /6	+ /2	+ /10	+ /6	--	+ /4	--
Smilacina stellata	--	--	--	--	--	*	--
Solidago graminifolia	+ /2	--	1/26	+ /8	--	--	--
Solidago missouriensis	1/16	1/12	+ /16	+ /4	--	--	--
Solidago mollis	--	--	--	--	--	--	+ /4
Solidago nemoralis	--	--	+ /4	--	--	+ /6	--
Thermopsis rhombifolia	+ /10	2/34	3/44	5/60	+ /4	5/34	2/32
Vicia americana	+ /18	1/12	--	--	--	--	+ /2
Species in microplots	36	34	39	37	26	32	22
Coverage of shrubs	77	88	74	58	90	102	99
Coverage of graminoids	52	55	65	57	55	46	34
Coverage of forbs	12	12	12	16	3	7	5
Total coverage	141	155	151	131	148	155	138

Table A-13.—*Rhus aromatica/Agropyron spicatum* and *Rhus aromatica/Festuca idahoensis* habitat types.

	Rhus/Agropyron					*Rhus/Festuca*	
Stand number	**111**	**131**	**33**	**36**	**39**	**87**	**88**
District	S	S	A	A	A	A	A
Location							
Quarter section	NE	NW	SW	SE	NW	SE	NE
Section	27	32	7	7	21	35	35
Township	2S	20N	7S	7S	6S	6S	6S
Range	62E	1E	47E	47E	45E	43E	43E
Topographic position							
Slope (%)	65	60	53	55	52	15	10
Aspect (°)	157	87	185	170	130	25	50
Elevation (m)	1,024	1,018	1,177	1,170	1,183	1,207	1,207
	Coverage/Frequency						
Shrubs							
Artemisia cana	+ /8	4/18	--	--	--	--	--
Artemisia frigida	+ /4	+ /2	--	*	--	2/16	1/2
Artemisia tridentata	--	--	--	--	+ /2	--	--
Chrysothamnus nauseosus	--	+ /2	--	--	--	--	--
Gutierrezia sarothrae	--	1/6	1/6	--	--	3/16	1/4
Opuntia fragilis	--	--	--	--	--	*	--
Opuntia polyacantha	--	--	--	--	--	+ /2	*
Rhus aromatica	28/66	36/70	29/54	27/50	31/56	25/30	22/34
Rosa arkansana	--	--	--	--	+ /4	--	--
Yucca glauca	+ /4	--	--	*	--	--	--
Graminoids							
Agropyron smithii	3/30	+ /2	3/30	10/68	9/60	+ /2	+ /2
Agropyron spicatum	34/96	33/92	47/86	49/96	36/86	61/96	51/78
Andropogon scoparius	1/6	--	--	--	+ /2	--	--
Aristida longiseta	+ /2	*	--	1/2	--	--	--
Bouteloua curtipendula	14/48	--	13/36	3/14	7/32	1/10	3/12
Bouteloua gracilis	4/22	4/18	--	--	--	--	--
Bromus japonicus	*	--	--	1/16	13/34	16/94	23/64
Bromus tectorum	--	--	+ /2	1/6	5/20	2/4	--
Calamovilfa longifolia	1/8	--	--	--	--	--	--
Carex filifolia	*	--	--	--	--	--	--
Carex heliophila	--	--	--	--	--	7/24	19/48

Stand number	Rhus/Agropyron 111	131	33	36	39	Rhus/Festuca 87	88
Distichlis spicata	--	*	--	--	--	--	--
Festuca idahoensis	--	--	--	--	--	4/16	26/54
Koeleria pyramidata	--	*	--	--	+/2	2/18	2/16
Muhlenbergia cuspidata	+/2	*	1/4	--	--	--	--
Oryzopsis hymenoides	+/2	1/6	--	--	--	--	--
Poa canbyi	--	--	--	--	--	12/38	4/16
Poa pratensis	--	--	--	+/2	--	--	--
Stipa comata	2/12	--	--	--	--	2/14	1/10
Stipa viridula	--	+/4	--	+/2	--	--	--
Forbs							
Achillea millefolium	--	--	--	--	*	+/4	*
Ambrosia psilostachya	*	--	5/40	1/14	1/20	1/8	2/28
Antennaria parvifolia	--	--	--	--	*	--	--
Artemisia dracunculus	--	--	--	--	--	--	1/4
Artemisia ludoviciana	--	--	--	--	--	1/6	--
Aster ericoides	--	--	+/2	2/12	*	+/4	+/2
Astragalus adsurgens	--	+/2	--	--	--	--	--
Cerastium arvense	--	--	--	--	--	1/8	1/4
Chrysopsis villosa	--	*	--	--	--	--	--
Cirsium undulatum	+/2	--	--	--	--	--	--
Eriogonum pauciflorum	--	+/2	--	--	--	--	--
Gaura coccinea	+/4	+/2	--	+/8	+/2	+/2	--
Hedeoma hispida	--	+/4	--	--	--	--	--
Kuhnia eupatorioides	--	+/2	--	--	--	--	--
Liatris punctata	--	+/2	--	--	--	--	--
Linum perenne	--	--	--	*	*	--	--
Lygodesmia juncea	--	--	--	--	+/2	--	--
Melilotus albus	--	1/4	--	--	--	--	--
Melilotus officinalis	--	8/42	--	+/2	--	--	--
Oxytropis sericea	--	--	--	--	--	+/8	--
Penstemon angustifolius	--	--	--	--	*	--	--
Phacelia hastata	--	--	1/4	--	--	--	--
Phlox hoodii	--	--	--	--	--	+/4	2/14
Psoralea argophylla	*	--	--	1/32	*	1/8	+/8
Sphaeralcea coccinea	1/18	--	1/8	+/18	+/8	--	--
Tragopogon dubius	+/4	*	--	*	--	--	--
Vicia americana	--	--	+/18	+/4	+/8	--	--
Bare ground	22/60	48/99	24/78	27/86	18/70	--	--
Species in microplots	18	18	12	16	15	23	18
Coverage of shrubs	28	41	30	27	31	30	24
Coverage of graminoids	59	38	64	65	70	107	129
Coverage of forbs	1	9	7	4	1	4	6
Total coverage	88	88	101	96	102	141	159

Table A-14.—*Rhus aromatica/Carex filifolia* habitat type.

Stand number	142	143	145	146
District	S	S	S	S
Location				
Quarter section	SE	SE	NW	SE
Section	21	21	24	23
Township	16N	16N	17N	17N
Range	9E	9E	7E	7E
Topographic position				
Slope (%)	30	20	20	60
Aspect (°)	357	322	177	177
Elevation (m)	1,000	1,006	1,097	1,085

	Coverage/Frequency			
Shrubs				
Artemisia cana	--	--	--	+/2
Artemisia frigida	4/46	5/54	5/68	2/26
Gutierrezia sarothrae	--	+/8	+/14	+/4
Juniperus horizontalis	--	--	--	+/2
Opuntia polyacantha	*	+/8	1/6	2/16
Rhus aromatica	35/48	29/40	22/38	15/28
Rosa arkansana	--	--	1/12	1/8
Symphoricarpos occidentalis	+/8	--	--	--
Toxicodendron rydbergii	3/8	--	--	--
Graminoids				
Agropyron dasystachyum	1/4	+/6	6/24	7/28
Andropogon scoparius	+/2	1/4	--	1/8
Bouteloua gracilis	--	1/10	15/50	2/10
Bromus japonicus	--	--	--	+/2
Calamovilfa longifolia	12/40	--	--	+/2
Carex filifolia	40/78	52/96	40/92	41/96
Carex heliophila	34/60	18/50	--	--
Koeleria pyramidata	3/30	6/46	6/44	+/8
Muhlenbergia cuspidata	22/50	25/68	1/8	8/44
Poa sandbergii	--	--	+/2	--
Stipa comata	11/44	6/40	13/66	1/10
Stipa viridula	--	--	1/4	--
Forbs				
Achillea millefolium	+/2	--	*	--
Allium textile	--	--	*	--
Anemone patens	+/2	—	+/2	+/2
Antennaria rosea	*	--	--	--
Artemisia campestris	--	1/4	+/4	--
Artemisia dracunculus	+/2	+/2	+/8	2/16
Aster ericoides	2/22	*	+/2	2/12
Astragalus adsurgens	1/10	+/2	1/4	*
Campanula rotundifolia	+/2	--	--	—
Cerastium arvense	--	--	+/2	--
Cirsium undulatum	1/8	*	+/2	+/4
Comandra umbellata	—	+/2	+/8	+/2
Echinacea angustifolia	+/2	1/10	+/4	+/2
Eriogonum flavum	--	+/2	--	--
Eriogonum pauciflorum	--	--	+/2	+/6
Gaura coccinea	—	+/2	--	+/2
Hedeoma hispida	--	--	+/2	--
Helianthus rigidus	+/2	*	--	--
Liatris punctata	+/2	+/4	*	--
Lupinus argenteus	--	—	3/4	—
Microseris cuspidata	+/6	+/20	+/2	*
Orthocarpus luteus	+/2	+/4	—	--
Oxytropis lambertii	--	--	--	+/2
Oxytropis sericea	--	--	+/2	--
Petalostemon purpureum	+/10	+/10	+/14	+/4
Phlox andicola	+/2	+/2	+/4	+/6
Phlox hoodii	--	--	*	+/4
Psoralea argophylla	+/2	--	--	--
Psoralea esculenta	—	--	+/6	--
Psoralea tenuiflora	+/2	--	--	*
Selaginella densa	--	*	--	--
Solidago missouriensis	--	*	--	+/8
Sphaeralcea coccinea	+/2	--	--	+/2
Tragopogon dubius	--	--	+/2	*
Bare ground	--	9/66	14/92	23/94
Species in microplots	29	24	31	30
Coverage of shrubs	42	34	29	20
Coverage of graminoids	123	109	82	60
Coverage of forbs	4	2	4	4
Total coverage	169	145	115	84

Table A-15.—*Sarcobatus vermiculatus/Agropyron spicatum* and *Sarcobatus vermiculatus/Agropyron smithii* habitat types.

	Sarcobatus vermiculatus/ Agropyron spicatum			***Sarcobatus vermiculatus/ Agropyron smithii***	
Stand number	**95**	**99**	**101**	**92**	**93**
District	A	A	A	A	A
Location					
Quarter section	SE	NW	SW	SE	SE
Section	13	4	10	5	4
Township	7S	5S	5S	7S	7S
Range	45E	44E	43E	43E	43E
Topographic position					
Slope (%)	45	80	70	3	5
Aspect (°)	265	225	185	335	210
Elevation (m)	1,061	1,042	975	1,006	1,000
	Coverage/Frequency				
Shrubs					
Artemisia frigida	--	--	--	*	--
Artemisia tridentata	1/8	8/24	3/14	--	--
Atriplex confertifolia	8/28	9/32	4/18	--	--
Chrysothamnus nauseosus	*	--	*	--	--
Gutierrezia sarothrae	1/4	3/28	*	--	--
Opuntia polyacantha	--	--	*	*	*
Sarcobatus vermiculatus	29/76	24/76	24/64	30/74	17/50
Graminoids					
Agropyron cristatum	--	--	--	--	+/4
Agropyron dasystachyum	--	--	3/4	--	--
Agropyron smithii	--	+/14	--	52/98	49/99
Agropyron spicatum	22/72	16/60	11/50	--	--
Bouteloua gracilis	--	--	--	+/2	--
Bromus japonicus	+/6	--	--	24/99	52/99
Bromus tectorum	--	--	--	7/16	--
Koeleria pyramidata	--	--	--	*	--
Oryzopsis hymenoides	1/6	+/4	--	--	--
Poa canbyi	+/2	--	--	15/78	8/48
Stipa viridula	--	--	--	--	2/4
Forbs					
Achillea millefolium	--	--	--	*	+/2
Camelina microcarpa	--	--	--	2/54	1/42
Erigonum pauciflorum	+/6	--	*	--	--
Suaeda depressa	--	1/26	--	--	--
Bare ground	52/94	76/99	77/99	--	--
Species in microplots	9	8	5	7	8
Coverage of shrubs	39	44	31	30	17
Coverage of graminoids	23	16	14	98	111
Coverage of forbs	0	1	0	2	1
Total coverage	62	61	45	130	129

Table A-16.—*Juniperus scopulorum/Agropyron spicatum* habitat type.

Stand number	89	90	94	100
District	A	A	A	A
Location				
Quarter section	NE	SE	SE	SW
Section	10	4	13	10
Township	7S	7S	7S	5S
Range	43E	43E	45E	43E
Topographic position				
Slope (%)	40	38	48	45
Aspect (°)	345	325	310	345
Elevation (m)	1,024	1,024	1,049	988
		Coverage/Frequency		
Shrubs				
Artemisia cana	+ /2	*	--	--
Artemisia filifolia	--	*	--	+ /2
Artemisia frigida	--	*	*	--
Artemisia tridentata	--	--	--	1/4
Gutierrezia sarothrae	+ /4	+ /16	+ /2	+ /4
Opuntia fragilis	--	--	--	*
Opuntia polyacantha	*	*	--	*
Prunus virginiana	*	2/4	*	--
Rhus aromatica	+ /4	--	3/8	*
Ribes odoratum	--	--	*	--
Rosa woodsii	+ /2	+ /2	--	+ /2
Sarcobatus vermiculatus	--	--	--	*
Symphoricarpos occidentalis	3/28	+ /2	1/8	*
Graminoids				
Agropyron caninum	--	--	+ /2	--
Agropyron smithii	--	--	2/6	--
Agropyron spicatum	40/94	26/96	29/98	18/92
Andropogon scoparius	--	--	*	1/2
Aristida longiseta	--	--	--	2/8
Bouteloua curtipendula	3/20	*	1/18	--
Bromus inermis	--	+ /8	--	--
Bromus japonicus	+ /2	--	1/14	--
Bromus tectorum	--	--	+ /2	--
Calamovilfa longifolia	4/22	--	--	2/6
Carex filifolia	--	--	*	1/4
Carex heliophila	+ /4	--	2/24	2/20
Koeleria pyramidata	+ /12	+ /4	+ /2	+ /12
Oryzopsis hymenoides	--	*	--	+ /2
Oryzopsis micrantha	--	+ /2	5/28	--
Poa canbyi	*	--	--	+ /4
Poa pratensis	--	--	2/10	--
Stipa viridula	--	--	*	--
Forbs				
Achillea millefolium	+ /14	+ /18	1/20	2/18
Anemone patens	--	--	--	+ /2
Antennaria rosea	*	--	+ /2	+ /2
Artemisia ludoviciana	+ /2	*	--	--
Aster ericoides	+ /2	--	--	--
Astragalus adsurgens	+ /6	2/22	--	1/8
Camelina microcarpa	--	--	--	*
Campanula rotundifolia	+ /6	*	+ /6	+ /8
Cerastium arvense	1/22	1/16	1/8	--
Ceratoides lanata	--	*	--	+ /2
Comandra umbellata	+ /16	1/16	--	--
Erigonum pauciflorum	--	+ /2	--	--
Gaura coccinea	—	+ /2	--	--
Geum triflorum	+ /2	1/2	--	--
Hedeoma drummondii	--	--	*	--
Hymenopappus filifolius	*	--	--	--
Liatrus punctata	--	--	--	+ /2
Linum perenne	--	--	+ /2	--
Linum rigidum	*	*	--	+ /2
Melilotus officinalis	--	--	*	--

Stand number	89	90	94	100
Mosses and lichens	--	--	7/22	2/14
Oxytropis sericea	--	+ /2	+ /6	+ /4
Petalostemon villosum	--	+ /2	--	--
Phlox hoodii	--	+ /6	--	--
Polygala alba	+ /2	--	+ /6	+ /4
Senecio canus	+ /2	--	--	--
Smilacina stellata	+ /10	--	--	--
Solidago missouriensis	1/12	*	+ /2	+ /6
Solidago rigida	+ /4	+ /4	--	--
Thermopsis rhombifolia	*	--	--	--
Vicia americana	*	--	--	--
Bare ground	62/98	64/99	46/92	70/99
Rocks	3/18	5/14	--	--
Species in microplots	24	19	22	25
Coverage of species	3	2	4	1
Coverage of graminoids	47	26	42	26
Coverage of forbs	2	5	9	5
Total coverage	52	33	55	32

Table A-17.—*Juniperus scopulorum/Oryzopsis micrantha* habitat type.

Stand number	123	126	128
District	S	S	S
Location			
Quarter section	SW	NE	NW
Section	20	1	1
Township	2S	2S	2S
Range	61E	60E	60E
Topographic position			
Slope (%)	30	55	65
Aspect (°)	27	317	337
Elevation (m)	1,097	1,085	1,024
	Coverage/Frequency		
Shrubs			
Artemisia frigida	+ /6	+ /2	+ /4
Artemisia tridentata	*	--	--
Berberis repens	3/50	1/8	+ /2
Chrysothamnus nauseosus	+ /2	--	*
Juniperus communis	--	*	7/20
Rhus aromatica	*	*	1/6
Ribes cereum	2/8	+ /4	+ /4
Ribes odoratum	*	*	--
Rosa woodsii	*	+ /2	--
Symphoricarpos albus	1/26	2/26	1/2
Symphoricarpos occidentalis	--	+ /2	+ /8
Toxicodendron rydbergii	--	--	+ /2
Graminoids			
Agropyron caninum	2/26	2/6	1/14
Agropyron dasystachyum	--	--	+ /4
Agropyron spicatum	--	+ /2	--
Andropogon scoparius	--	+ /4	--
Bromus japonicus	1/16	--	+ /2
Carex filifolia	--	--	*
Carex heliophila	1/24	1/6	2/20
Koeleria pyramidata	+ /4	*	+ /4
Muhlenbergia cuspidata	*	--	--
Oryzopsis micrantha	61/94	38/96	40/86
Poa canbyi	--	--	2/8
Poa sandbergii	*	+ /2	--
Stipa occidentalis	+ /6	--	--
Stipa viridula	--	--	+ /2
Forbs			
Achillea millefolium	1/22	+ /6	1/20
Anemone patens	--	+ /2	--
Antennaria parvifolia	--	--	+ /2
Antennaria rosea	+ /10	1/10	+ /10
Arabis hirsuta	+ /14	--	--
Astragalus adsurgens	--	--	2/6
Astragalus racemosus	--	--	1/4
Campanula rotundifolia	+ /18	+ /2	2/40
Cerastium arvense	1/24	+ /6	--
Disporum trachycarpum	--	*	--
Galium boreale	--	+ /2	+ /6
Geum triflorum	--	+ /2	--
Hedeoma hispida	+ /2	--	--
Heuchera richardsonii	+ /2	*	--
Mosses and lichens	--	43/78	+ /6
Oxytropis lambertii	--	--	*
Smilacina stellata	4/64	*	4/34
Solidago missouriensis	+ /2	+ /2	1/20
Bare ground	48/99	34/74	49/98
Species in microplots	20	21	26
Coverage of shrubs	6	3	9
Coverage of graminoids	65	41	45
Coverage of forbs	6	44	11
Total coverage	77	88	65

Table A-18.—*Fraxinus pennsylvanica/Prunus virginiana* habitat type.

Stand number	7	9	15	68	72	84	47	115	120	147	27	28	85	110
District	G	G	G	G	G	G	S	S	S	S	A	A	A	A
Location														
Quarter section	SE	NE	NE	SW	SE	SE	SW	NE	SE	SW	SE	SE	SE	SW
Section	14	31	33	5	28	28	25	33	31	6	22	22	26	35
Township	20N	19N	19N	20N	20N	22N	19N	1N	2S	16N	3S	3S	7S	5S
Range	15E	13E	18E	16E	13E	13E	7E	58E	62E	8E	47E	47E	46E	44E
Topographic position														
Slope (%)	10	7	3	2	4	5	18	8	7	40	2	2	7	3
Aspect (°)	253	93	338	18	8	33	282	47	357	347	260	260	305	355
Elevation (m)	--	—	--	—	—	--	1,036	1,146	1,085	1,091	1,155	1,155	1,128	1,091
							Coverage/Frequency							
Shrubs														
Amelanchier alnifolia	7/14	--	--	1/2	--	—	+ /2	--	--	8/24	•	6/8	--	--
Amelanchier sanguinea	2/4	•	--	--	•	1/4	+ /2	--	2/6	3/10	--	--	2/6	--
Artemisia frigida	--	--	--	•	--	+ /2	•	--	--	--	--	--	--	--
Berberis repens	--	--	--	--	--	--	--	14/72	+ /2	--	19/54	32/94	3/26	•
Celastrus scandens	--	--	--	--	--	7/32	--	--	--	--	--	--	--	--
Clematis ligusticifolia	--	--	--	--	--	4/18	--	--	•	--	--	--	--	1/6
Cornus stolonifera	--	--	--	--	--	--	+ /6	--	--	--	--	--	--	--
Crataegus succulenta	--	--	--	•	•	--	--	+ /2	8/12	--	20/30	5/10	4/6	•
Juniperus communis	--	--	--	--	--	—	--	--	--	2/4	—	--	--	--
Parthenocissus vitacea	3/12	--	+ /2	•	--	1/10	+ /2	—	--	+ /4	--	•	—	--
Prunus americana	--	--	12/38	•	•	--	--	1/4	•	•	13/36	5/18	•	8/12
Prunus virginiana	75/94	43/58	--	29/70	70/96	55/84	87/99	88/98	14/50	79/99	79/96	70/99	5/24	46/78
Rhus aromatica	•	--	--	--	•	•	--	--	--	+ /2	--	--	--	--
Ribes americanum	--	--	--	--	--	--	1/6	--	+ /2	--	--	--	1/2	--
Ribes cereum	--	--	--	--	--	--	--	--	•	--	--	--	--	--
Ribes missouriense	--	--	--	--	--	--	+ /2	•	•	+ /4	--	--	1/8	2/6
Ribes odoratum	1/8	•	--	•	•	•	+ /2	—	9/26	•	8/22	1/6	--	1/6
Ribes setosum	--	+ /2	--	--	--	--	--	--	--	--	3/22	3/32	—	--
Rosa acicularis	3/14	--	--	--	--	--	--	--	--	--	--	--	--	--
Rosa woodsii	3/8	--	--	•	--	1/8	+ /6	--	+ /2	+ /4	6/26	4/14	--	•
Rubus idaeus	--	--	--	--	--	--	•	+ /2	•	--	--	--	--	--
Shepherdia argentea	--	•	--	--	--	--	--	--	--	--	--	--	--	--
Symphoricarpos albus	--	—	--	—	--	--	--	--	--	--	6/30	6/34	--	—
Symphoricarpos occidentalis	22/46	5/32	2/14	+ /6	•	30/84	1/18	--	2/12	2/16	—	4/24	1/6	•
Toxicodendron rydbergii	3/8	--	•	+ /4	—	3/12	1/10	1/12	3/20	+ /4	--	--	•	•
Vitis vulpina	--	—	—	•	•	--	--	--	—	--	—	--	--	--
Graminoids														
Agropyron caninum	+ /4	7/30	—	16/78	+ /2	35/68	+ /2	--	3/10	2/10	+ /4	+ /2	--	--
Bouteloua curtipendula	--	--	--	--	--	--	--	•	--	--	—	--	—	--
Bromus carinatus	--	--	—	2/18	--	--	--	—	--	—	--	—	--	—
Bromus inermis	+ /2	19/24	--	—	--	3/4	--	--	--	--	--	--	—	•
Bromus japonicus	--	+ /2	--	—	20/52	--	--	—	5/18	—	—	--	--	--
Bromus tectorum	--	--	—	--	2/10	--	--	--	—	—	--	—	--	—
Carex gravida	1/4	1/4	1/8	1/12	2/6	--	--	--	5/6	--	--	--	--	--
Carex sprengelii	3/6	7/12	77/90	8/28	26/50	+ /2	46/88	52/80	1/2	30/52	41/62	21/44	56/74	74/96
Elymus canadensis	--	--	--	--	--	--	9/46	20/62	1/6	--	--	--	--	•
Elymus virginicus	23/50	46/76	14/56	—	9/36	6/18	--	1/6	26/68	39/98	3/16	3/14	1/8	25/64
Muhlenbergia racemosa	--	--	--	--	--	--	--	--	4/18	--	--	--	—	--
Oryzopsis micrantha	41/58	9/18	--	--	1/6	11/28	+ /4	--	--	2/12	--	--	--	--
Poa compressa	--	--	--	--	--	--	--	--	--	2/12	—	—	--	—
Poa palustris	—	--	--	—	--	--	2/8	—	2/4	--	--	--	—	--
Poa pratensis	4/10	27/54	—	52/80	37/70	5/14	—	—	48/72	•	17/30	8/20	—	1/6
Poa sandbergii	--	—	—	--	--	—	--	--	--	•	--	--	--	—
Stipa viridula	•	1/2	--	--	1/4	--	--	—	—	--	—	—	--	--
Forbs														
Achillea millefolium	—	•	--	--	1/6	--	+ /2	—	1/2	+ /2	—	--	--	--
Ambrosia psilostachya	--	--	--	+ /4	--	—	--	--	--	--	—	—	--	--
Ambrosia trifida	--	—	1/14	--	--	--	--	—	--	--	—	--	--	—
Apocynum androsaemifolium	--	--	--	--	—	•	--	—	1/4	—	--	--	--	—
Arctium minus	--	44/72	--	--	--	--	—	--	•	—	—	—	+ /2	--
Artemisia ludoviciana	--	•	--	--	•	—	--	—	•	—	—	--	—	--
Campanula rotundifolia	--	--	--	--	--	--	+ /2	--	--	—	--	--	--	--
Chenopodium album	--	—	+ /2	+ /2	—	—	--	--	--	--	--	--	—	--
Convolvulus arvense	—	--	+ /8	+ /4	1/10	—	+ /2	—	1/16	--	+ /2	—	—	—
Cystopteris fragilis	4/18	--	--	--	--	--	8/84	—	--	--	--	--	1/4	--
Disporum trachycarpum	+ /6	--	--	--	--	—	+ /2	--	•	•	—	1/16	+ /6	•
Erysimum cheiranthoides	—	--	1/6	--	--	—	--	—	—	--	—	--	--	--
Fragaria virginiana	--	—	--	--	—	--	+ /10	--	--	3/36	--	•	--	--
Galium aparine	4/32	9/42	6/36	9/60	22/90	--	+ /8	1/10	--	--	11/48	5/34	19/56	3/12
Galium boreale	--	--	--	--	--	—	3/28	+ /2	13/48	4/36	•	9/40	—	1/6
Geum canadense	--	--	--	—	--	--	--	--	—	--	--	--	•	--
Hackelia deflexa	--	+ /2	10/36	•	•	+ /2	1/10	•	+ /2	--	--	--	--	+ /2
Hackelia floribunda	--	--	--	--	--	--	--	--	—	--	1/8	•	1/12	•
Hesperis matronalis	--	--	--	--	—	--	--	—	--	--	--	--	35/80	--
Heuchera richardsonii	--	--	--	--	--	--	+ /2	--	--	3/14	--	--	--	--
Humulus lupulus	--	—	--	—	--	--	--	--	--	—	--	--	•	--
Lactuca oblongifolia	--	--	--	--	2/14	+ /2	--	--	+ /6	--	--	--	--	--
Lactuca serriola	--	--	--	--	--	--	--	--	--	—	•	—	--	--
Melilotus officinalis	•	+ /2	+ /6	6/54	6/34	21/72	—	—	--	--	—	--	--	--

Stand number	7	9	15	68	72	84	47	115	120	147	27	28	85	110
Mirabilis nyctaginea	--	--	--	--	*	--	--	--	--	--	--	--	--	--
Monarda fistulosa	+ /6	*	+ /2	*	*	2/10	+ /2	--	6/26	*	+ /4	*	--	*
Mosses and lichens	*	--	--	--	--	--	--	--	--	--	--	--	--	--
Nepeta cataria	--	+ /6	*	--	--	--	--	--	4/18	--	--	--	+ /2	--
Osmorhiza claytonii	--	--	--	--	--	--	--	1/8	--	--	--	--	--	--
Osmorhiza longistylis	--	--	2/28	--	--	--	3/28	--	+ /2	--	+ /4	1/10	27/82	--
Parietaria pennsylvanica	5/36	4/36	2/12	1/18	2/18	1/4	+ /12	--	+ /4	--	4/20	--	--	--
Polygonatum biflorum	1/8	--	--	--	--	--	--	--	--	--	--	+ /2	--	--
Ranunculus abortivus	--	--	--	+ /2	--	--	--	--	--	--	--	--	+ /4	--
Ranunculus cymbalaria	--	--	+ /2	--	--	--	--	--	--	--	--	--	--	--
Sanicula marilandica	--	--	--	--	--	--	--	1/14	1/2	--	--	--	--	11/48
Smilacina stellata	21/58	+ /4	2/16	--	+ /4	3/24	+ /18	1/16	1/14	5/64	3/26	2/24	2/18	--
Smilax herbacea	2/14	--	1/6	*	2/8	+ /2	--	--	*	*	*	1/8	*	3/14
Solidago canadensis	--	--	--	--	--	4/18	--	--	--	--	--	--	--	--
Solidago missouriensis	--	--	--	--	--	--	2/8	--	--	--	--	--	--	--
Taraxacum officinale	--	4/34	+ /4	10/72	6/40	1/6	+ /4	--	--	--	--	--	1/6	--
Thalictrum dasycarpum	--	--	2/10	--	1/10	--	*	2/26	+ /4	1/4	+ /2	2/4	+ /8	1/14
Thalictrum venulosum	--	--	--	--	--	--	*	--	--	--	*	--	--	+ /4
Tragopogon dubius	--	1/4	--	*	--	--	--	--	--	--	--	--	--	--
Urtica dioica	--	--	*	--	--	--	*	+ /6	--	--	--	--	2/12	--
Vicia americana	+ /2	--	--	--	--	--	--	--	--	--	--	--	--	--
Viola canadensis	--	--	--	--	--	*	--	1/16	*	--	28/58	--	--	6/8
Viola pratincola	1/10	+ /2	--	--	--	--	--	--	--	--	--	--	--	--
Species in microplots	26	22	21	17	20	24	32	17	31	21	21	22	22	16
Coverage of shrubs	119	48	14	30	70	102	90	104	38	94	154	136	17	58
Coverage of graminoids	72	117	92	79	98	60	57	73	95	75	61	32	57	100
Coverage of forbs	38	62	27	26	43	32	17	7	28	16	47	21	88	25
Total coverage	229	227	133	135	211	194	164	184	161	185	262	189	162	183

Table A-19.—Disturbed stands of the *Fraxinus pennsylvanica*/ *Prunus virginiana* habitat type.

Stand number	166	167	168
District	S	G	S
Location			
Quarter Section	NE	NW	NE
Section	11	13	31
Township	3S	20N	17N
Range	61E	15E	8E
Topographic position			
Slope (%)	2	2	2
Aspect (°)	177	68	177
Elevation (m)	1,109	--	994
	Coverage/Frequency		
Shrubs			
Artemisia cana	--	--	2/14
Artemisia frigida	--	+ /4	1/16
Berberis repens	+ /2	--	--
Crataegus succulenta	9/32	*	--
Opuntia polyacantha	--	--	1/2
Prunus virginiana	+ /2	*	--
Ribes americanum	--	--	*
Ribes missouriense	*	--	--
Ribes odoratum	+ /2	--	--
Rosa woodsii	--	*	--
Symphoricarpos albus	+ /2	--	--
Symphoricarpos occidentalis	6/56	4/24	7/42
Graminoids			
Agropyron caninum	22/56	9/40	--
Agropyron cristatum	--	*	--
Agropyron smithii	--	--	18/99
Bouteloua gracilis	--	--	4/6
Bromus carinatus	2/16	--	--
Bromus japonicus	1/18	+ /2	1/26
Bromus mollis	+ /2	--	--
Carex gravida	+ /4	--	--
Elymus virginicus	3/12	--	--
Poa compressa	--	9/48	--
Poa pratensis	87/99	86/99	77/99
Stipa viridula	7/20	+ /4	2/26
Forbs			
Achillea millefolium	3/52	+ /8	2/44
Artemisia dracunculus	--	--	*
Artemisia ludoviciana	+ /4	+ /2	--
Aster ericoides	*	--	1/18
Cerastium arvense	+ /2	--	--
Collomia linearis	+ /2	--	--
Galium boreale	2/10	--	--
Grindelia squarrosa	--	+ /2	1/12
Monarda fistulosa	1/12	1/4	--
Nepeta cataria	--	*	--
Potentilla gracilis	+ /2	--	--
Ratibida columnifera	*	*	--
Smilacina stellata	*	--	--
Smilax herbacea	*	--	--
Solidago rigida	--	+ /2	--
Taraxacum officinale	+ /2	--	--
Tragopogon dubius	*	+ /4	--
Vicia americana	2/18	--	--
Bare ground	--	4/6	10/90
Fallen trees	--	8/16	--
Species in microplots	23	13	12
Coverage of shrubs	15	4	11
Coverage of graminoids	122	104	102
Coverage of forbs	8	1	4
Total coverage	145	109	117

Table A-20.—*Populus tremuloides/Berberis repens* habitat type.

Stand number	53	54	114	117
District	S	S	S	S
Location				
Quarter section	NW	SW	NW	NE
Section	31	36	20	20
Township	2S	2S	1N	1N
Range	62E	61E	58E	58E
Topographic position				
Slope (%)	2	7	2	15
Aspect (°)	347	2	267	52
Elevation (m)	1,097	1,134	1,164	1,170
	Coverage/Frequency			
Shrubs				
Amelanchier alnifolia	13/38	+ /2	--	--
Amelanchier sanguinea	--	--	+ /4	2/32
Berberis repens	47/96	27/94	52/99	56/99
Cornus stolonifera	--	*	--	--
Crataegus chrysocarpa	2/6	+ /8	--	--
Crataegus succulenta	--	--	*	--
Juniperus communis	--	*	--	--
Parthenocissus vitacea	1/8	--	--	--
Prunus americana	*	1/4	--	--
Prunus virginiana	2/28	10/52	5/40	4/46
Rhus aromatica	--	*	--	--
Ribes missouriense	+ /4	+ /2	1/8	1/8
Ribes odoratum	--	*	--	--
Rosa acicularis	--	--	--	*
Rosa woodsii	*	+ /2	--	--
Rubus idaeus	+ /4	5/30	2/28	2/26
Symphoricarpos albus	6/54	2/12	2/24	7/56
Symphoricarpos occidentalis	1/10	1/14	4/52	*
Toxicodendron rydbergii	+ /6	2/24	3/34	+ /6
Graminoids				
Agropyron caninum	--	*	+ /4	6/30
Bromus ciliatus	--	9/48	--	--
Bromus kalmii	1/6	10/22	--	--
Carex gravida	+ /2	--	2/4	--
Carex sprengelii	3/8	8/46	25/66	--
Carex xerantica	--	1/28	--	--
Danthonia spicata	--	--	*	+ /2
Elymus canadensis	--	--	1/4	1/4
Elymus virginicus	7/52	12/74	2/16	--
Muhlenbergia racemosa	*	--	--	--
Poa pratensis	36/62	4/12	23/66	81/99
Schizachne purpurascens	--	--	14/68	9/42
Stipa occidentalis	--	--	--	*
Forbs				
Achillea millefolium	*	+ /2	--	+ /2
Apocynum androsaemifolium	2/16	--	+ /4	4/54
Campanula rotundifolia	+ /2	+ /2	+ /2	--
Cystopteris fragilis	+ /4	--	--	--
Disporum trachycarpum	+ /2	+ /4	+ /6	*
Fragaria virginiana	*	2/20	--	+ /2
Galium aparine	--	--	1/20	--
Galium boreale	12/74	5/44	2/40	5/56
Galium triflorum	--	6/50	--	--
Hackelia deflexa	--	+ /2	--	--
Heuchera richardsonii	*	--	--	--
Lupinus argenteus	--	--	--	*
Lysimachia ciliata	--	3/48	--	--
Melilotus officinalis	+ /2	--	--	--
Monarda fistulosa	*	1/6	+ /6	1/6
Osmorhiza longistylis	+ /2	3/12	--	--
Parietaria pennsylvanica	+ /2	--	--	--
Ranunculus abortivus	--	1/10	--	--
Sanicula marilandica	2/48	2/16	--	1/10

Stand number	53	54	114	117
Smilacina stellata	+ /14	+ /4	+ /10	+ /2
Smilax herbacea	--	--	+ /2	--
Solidago missouriensis	--	--	--	*
Taraxacum officinale	+ /6	+ /18	--	--
Thalictrum dasycarpum	2/18	3/38	--	1/12
Thermopsis rhombifolia	--	--	--	+ /10
Tragopogon dubius	*	--	--	--
Viola canadensis	--	2/16	--	--
Species in microplots	27	33	23	21
Coverage of shrubs	72	48	69	72
Coverage of graminoids	47	44	67	97
Coverage of forbs	18	28	3	12
Total coverage	137	120	139	181

Table A-21.—*Pinus ponderosa/Agropyron spicatum* habitat type.

Stand number	165	152	154
District	S	A	A
Location			
Quarter section	SE	NE	SW
Section	15	2	23
Township	3S	4S	3S
Range	62E	47E	47E
Topographic position			
Slope (%)	43	35	35
Aspect (°)	85	200	170
Elevation (m)	1,049	1,225	1,231
	Coverage/Frequency		
Shrubs			
Artemisia frigida	+ /2	+ /4	--
Opuntia polyacantha	*	--	--
Prunus virginiana	*	--	--
Rhus aromatica	2/8	1/6	1/2
Ribes cereum	*	--	--
Ribes missouriense	--	*	--
Rosa acicularis	--	+ /2	--
Graminoids			
Agropyron smithii	--	--	*
Agropyron spicatum	43/96	17/88	37/84
Andropogon gerardi	+ /2	--	*
Andropogon scoparius	--	--	1/12
Bouteloua curtipendula	3/20	--	1/6
Bromus japonicus	+ /2	--	--
Bromus tectorum	*	--	*
Calamovilfa longifolia	1/6	--	*
Carex filifolia	6/31	--	--
Carex heliophila	4/36	2/14	38/90
Festuca idahoensis	--	--	+ /6
Koeleria pyramidata	--	--	+ /2
Poa canbyi	--	--	*
Stipa comata	1/4	--	--
Stipa spartea	--	--	+ /4
Stipa viridula	--	--	*
Forbs			
Achillea millefolium	--	+ /2	--
Allium textile	+ /2	--	--
Antennaria plantaginifolia	--	--	+ /2
Artemisia ludoviciana	--	+ /2	+ /4
Aster ericoides	--	+ /2	+ /6
Astragalus adsurgens	--	+ /2	+ /2
Balsamorhiza sagittata	--	--	+ /2
Calochortus nuttallii	--	--	*
Cerastium arvense	--	1/12	--
Chrysopsis villosa	+ /2	--	--
Cirsium undulatum	--	--	+ /2
Collomia linearis	--	+ /4	+ /4
Helianthus rigidus	--	*	*
Liatrus punctata	+ /6	--	--
Lupinus argenteus	--	+ /2	--
Petalostemon candidum	+ /2	--	--
Petalostemon purpureum	--	+ /6	--
Phacelia linearis	--	3/24	--
Psoralea argophylla	--	--	*
Psoralea esculenta	--	*	*
Solidago graminifolia	--	--	+ /2
Solidago speciosa	--	+ /2	*
Sphaeralcea coccinea	+ /8	--	--
Thermopsis rhombifolia	--	+ /2	--
Vicia americana	--	--	2/20
Species in microplots	15	17	17
Coverage of shrubs	2	1	1
Coverage of graminoids	58	19	77
Coverage of forbs	0	4	2
Total coverage	60	24	80

Table A-22.—*Pinus ponderosa/Festuca idahoensis* and *Pinus ponderosa/Carex heliophila* habitat types.

	Pinus/Festuca		*Pinus/Carex*		
Stand number	**156**	**157**	**159**	**160**	**153**
District	A	A	S	S	A
Location					
Quarter section	SW	NE	SE	SE	SW
Section	15	31	25	26	23
Township	6S	5S	1N	1N	4S
Range	44E	44E	58E	58E	47E
Topographic position					
Slope (%)	8	10	--	3	15
Aspect (°)	215	355	--	207	150
Elevation (m)	1,250	1,237	1,213	1,225	1,244
	Coverage/Frequency				
Shrubs					
Amelanchier alnifolia	--	--	*	*	--
Artemisia frigida	--	--	--	--	*
Juniperus scopulorum	--	*	--	--	--
Rhus aromatica	--	--	*	*	+/2
Ribes cereum	--	--	*	+/2	--
Ribes missouriense	--	--	*	--	--
Rosa woodsii	--	+/10	--	--	--
Symphoricarpos albus	*	*	1/2	--	--
Graminoids					
Agropyron caninum	--	--	*	1/18	--
Agropyron dasystachyum	--	--	+/4	--	--
Agropyron smithii	*	--	--	--	--
Agropyron spicatum	4/42	1/16	3/42	+/2	+/4
Andropogon gerardi	+/6	*	--	1/4	+/4
Bouteloua curtipendula	*	1/18	--	--	--
Calamovilfa longifolia	1/4	--	--	--	--
Carex filifolia	--	--	1/6	--	--
Carex heliophila	9/46	40/96	69/99	75/99	81/99
Festuca idahoensis	33/72	49/92	--	--	2/18
Festuca ovina	--	--	*	--	--
Koeleria pyramidata	+/2	*	*	--	*
Poa canbyi	+/2	--	--	--	--
Stipa comata	--	1/8	+/2	--	*
Stipa occidentalis	--	--	--	--	+/2
Stipa spartea	--	--	--	8/42	--
Stipa viridula	*	*	--	--	--
Forbs					
Achillea millefolium	+/6	1/16	--	--	--
Anemone patens	--	--	+/2	+/2	--
Antennaria plantaginifolia	--	--	--	1/6	+/4
Antennaria rosea	+/2	1/32	*	--	--
Artemisia ludoviciana	+/2	1/14	--	*	+/2
Aster ericoides	--	+/6	--	+/2	*
Aster laevis	--	*	--	--	--
Astragalus adsurgens	+/8	--	--	--	--
Astragalus agrestis	+/2	1/14	--	--	--
Balsamorhiza sagittata	--	+/8	--	--	+/2
Campanula rotundifolia	*	+/2	--	--	*
Cerastium arvense	+/2	1/22	*	--	*
Chrysopsis villosa	*	--	--	--	--
Collomia linearis	*	+/2	--	*	+/2
Echinacea angustifolia	--	*	--	--	--
Fragaria virginiana	--	*	--	--	--
Geum triflorum	--	+/2	--	--	--
Liatris punctata	--	--	--	*	+/2
Lupinus argenteus	--	+/2	--	--	*
Oxytropis sericea	*	--	--	--	--
Psoralea argophylla	*	+/2	--	--	--
Psoralea esculenta	--	+/2	--	*	--
Solidago graminifolia	*	--	--	--	--

Stand number	Pinus/Festuca 156	Pinus/Festuca 157	Pinus/Carex 159	Pinus/Carex 160	Pinus/Carex 153
Solidago rigida	--	+/2	--	*	--
Thermopsis rhombifolia	--	--	--	1/8	--
Tragopogon dubius	--	+/2	--	*	--
Vicia americana	--	+/6	--	--	*
Leaf litter	70/99	61/99	58/99	59/99	67/99
Species in microplots	13	22	7	10	11
Coverage of shrubs	0	0	1	0	0
Coverage of graminoids	47	92	73	85	83
Coverage of forbs	0	5	0	2	0
Total coverage	47	97	74	87	83

Table A-23.—*Pinus ponderosa/Juniperus communis* habitat type.

Stand number	161	162
District	S	S
Location		
Quarter section	SE	SW
Section	26	33
Township	1N	1N
Range	58E	58E
Topographic position		
Slope (%)	25	35
Aspect (°)	347	47
Elevation (m)	1,219	1,244
	Coverage/Frequency	
Shrubs		
Amelanchier alnifolia	+/4	--
Berberis repens	1/10	*
Juniperus communis	38/56	41/54
Prunus virginiana	*	+/8
Rhus aromatica	*	+/2
Ribes cereum	+/2	+/2
Ribes missouriense	*	*
Rosa acicularis	--	*
Symphoricarpos albus	*	+/2
Toxicodendron rydbergii	--	*
Vaccinium scoparium	--	+/2
Graminoids		
Agropyron caninum	*	--
Calamovilfa longifolia	+/4	--
Carex heliophila	34/68	18/54
Danthonia spicata	1/4	1/12
Festuca idahoensis	1/2	+/2
Festuca ovina	+/2	*
Koeleria pyramidata	--	*
Stipa occidentalis	+/2	--
Stipa viridula	--	+/6
Forbs		
Achillea millefolium	--	*
Antennaria plantaginifolia	*	+/6
Cerastium arvense	*	*
Geum triflorum	--	*
Pterospora andromedea	--	*
Smilacina stellata	*	*
Solidago mollis	1/6	--
Thermopsis rhombifolia	--	1/6
Leaf litter	56/99	77/99
Species in microplots	11	12
Coverage of shrubs	39	41
Coverage of graminoids	36	19
Coverage of forbs	1	1
Total coverage	76	61

Table A-24.—*Pinus ponderosa/Prunus virginiana* habitat type.

Stand number	163	164	169	155	158
District	S	S	S	A	A
Location					
Quarter section	NE	NE	NE	NW	NW
Section	2	2	7	14	30
Township	3S	3S	18N	3S	2S
Range	61E	61E	8E	47E	47E
Topographic position					
Slope (%)	2	20	35	35	40
Aspect (°)	187	2	337	355	10
Elevation (m)	1,213	1,207	1,061	1,292	1,256
			Coverage/Frequency		
Shrubs					
Amelanchier alnifolia	2/12	6/38	8/30	11/42	5/12
Berberis repens	3/22	47/99	*	32/88	48/98
Crataegus succulenta	--	--	--	*	1/4
Fraxinus pennsylvanica	--	--	1/10	--	*
Prunus virginiana	30/96	44/88	31/92	48/84	65/94
Rhus aromatica	--	--	*	*	*
Ribes missouriense	--	+ /2	3/12	2/24	1/4
Ribes odoratum	--	--	--	--	1/4
Rosa woodsii	--	+ /4	7/38	8/42	2/20
Symphoricarpos albus	--	*	1/8	2/16	+ /6
Symphoricarpos occidentalis	--	*	1/8	--	--
Toxicodendron rydbergii	--	2/18	1/4	22/68	7/38
Graminoids					
Agropyron caninum	--	2/6	7/48	7/46	5/36
Agrostis scabra	--	5/22	--	--	--
Bromus carinatus	--	--	--	--	*
Bromus ciliatus	--	--	--	2/14	--
Carex heliophila	65/99	36/42	+ /2	--	--
Carex hoodii	--	--	--	1/4	--
Danthonia spicata	4/26	1/4	--	--	--
Elymus canadensis	--	3/16	5/26	--	--
Elymus virginicus	--	--	--	+ /2	+ /2
Festuca idahoensis	--	--	--	*	--
Muhlenbergia cuspidata	--	+ /4	--	--	--
Oryzopsis micrantha	--	--	+ /2	--	--
Poa compressa	--	--	3/14	--	--
Poa fendleriana	--	--	--	--	10/30
Poa interior	--	--	--	15/38	--
Poa pratensis	+ /2	2/4	7/10	5/22	2/12
Schizachne purpurascens	+ /2	1/4	10/20	3/26	--
Stipa occidentalis	16/62	1/6	--	--	--
Stipa spartea	1/4	--	--	--	--
Stipa viridula	--	+ /2	--	--	--
Forbs					
Achillea millefolium	--	*	--	+ /2	*
Antennaria plantaginifolia	--	--	+ /2	--	--
Apocynum androsaemifolium	--	2/20	--	--	6/32
Artemisia ludoviciana	*	--	--	*	*
Aster ericoides	--	--	--	*	--
Campanula rotundifolia	--	+ /4	+ /2	*	1/6
Cerastium arvense	*	--	--	--	--
Disporum trachycarpum	--	--	--	7/36	1/12
Erigeron subtrinervis	--	--	--	--	*
Fragaria virginiana	--	--	--	1/14	*
Galium boreale	5/28	2/16	4/34	10/60	4/42
Geum triflorum	--	--	--	1/12	--
Heuchera richardsonii	--	--	2/14	--	+ /4
Monarda fistulosa	--	--	--	*	*
Osmorhiza longistylis	--	--	--	+ /2	--
Perideridia gairdneri	--	--	--	*	--
Sanicula marilandica	--	--	--	--	+ /2
Smilacina racemosa	--	--	--	*	--
Smilacina stellata	+ /2	2/22	1/8	1/14	*

Stand number	163	164	169	155	158
Smilax herbacea	--	--	--	+/2	--
Solidago gigantea	--	2/16	--	--	--
Solidago mollis	+/6	--	--	--	--
Taraxacum officinale	--	--	--	+/2	--
Thalictrum dasycarpum	--	2/20	--	--	--
Tragopogon dubius	*	--	--	*	--
Vicia americana	2/10	+/4	--	+/2	--
Zigadenus venenosus	+/4	--	--	--	--
Species in microplots	14	23	20	24	19
Coverage of shrubs	35	99	53	125	130
Coverage of graminoids	86	51	32	33	17
Coverage of forbs	7	10	7	20	12
Total coverage	128	160	92	178	159

Table A-25.—*Shepherdia argentea* and *Symphoricarpos occidentalis* community types.

Species	***Shepherdia argentea*** (n = 11)	***Symphoricarpos occidentalis*** (n = 2)
	Coverage/Frequency	
Shrubs		
Amelanchier sanguinea	4/27	--
Artemisia cana	+/9	--
Artemisia frigida	1/45	--
Cornus stolonifera	+/9	--
Crataegus succulenta	+/9	--
Fraxinus pennsylvanica	+/9	--
Juniperus horizontalis	2/18	--
Parthenocissus vitacea	2/18	--
Pinus ponderosa	+/9	--
Prunus virginiana	7/27	--
Rhus aromatica	1/45	--
Ribes americanum	2/18	--
Ribes missouriense	+/18	--
Ribes odoratum	15/55	--
Ribes setosum	--	8/50
Rosa acicularis	+/9	--
Rosa woodsii	4/100	--
Rubus idaeus	1/9	--
Shepherdia argentea	81/100	--
Symphoricarpos occidentalis	79/100	92/100
Toxicodendron rydbergii	7/82	--
Graminoids		
Agropyron caninum	7/64	--
Agropyron smithii	1/45	1/50
Andropogon gerardi	+/9	--
Andropogon scoparius	+/18	--
Bromus japonicus	19/27	1/50
Carex filifolia	+/9	--
Elymus canadensis	+/9	--
Koeleria pyramidata	+/18	--
Poa pratensis	69/100	20/100
Stipa viridula	1/27	--
Forbs		
Achillea millefolium	6/55	--
Anemone canadensis	1/27	--
Antennaria rosea	+/9	--
Artemisia ludoviciana	4/73	8/50
Chenopodium album	+/18	--
Chenopodium capitatum	1/9	--
Cirsium arvense	2/18	--
Cirsium undulatum	+/9	--
Convolvulus arvensis	1/27	1/50
Galium aparine	7/45	3/100
Galium boreale	2/18	--
Glycyrrhiza lepidota	1/36	--
Hackelia deflexa	2/18	--
Lactuca oblongifolia	+/18	--
Lupinus argenteus	+/9	--
Melilotus officinalis	+/18	--
Monarda fistulosa	5/73	--
Nepeta cataria	3/55	--
Panicum virgatum	+/9	--
Parietaria pennsylvanica	28/100	9/100
Psoralea argophylla	+/18	--
Ratibida columnifera	+/9	--
Sanicula marilandica	1/27	--
Smilacina stellata	+/18	--
Solidago rigida	+/9	--
Taraxacum officinale	2/45	--
Urtica dioica	1/36	19/50
Vicia americana	+/18	--
Viola canadensis	+/9	--

Appendix 3. Soil Analyses

Table A-26.—Selected edaphic characteristics of the upper 1 dm of mineral soil for habitat types on the Custer National Forest. All values are ranges for the stands in each habitat type.

No. of stands	pH	Mechanical analysis % Sand	% Silt (Texture)	% Clay	Exchangeable cations (meq/100 g) Ca	Mg	K	P (ppm)	C.E.C.[1] (meq/ 100 g)	O.M.[2] (%)
				Stipa comata/Carex filifolia **habitat type**						
18	5.9-7.5	38.0-78.5	17.5-47.0	3.0-18.0	5.0-22.3	1.0-4.6	0.26-2.12	8.0-14.5	6.93-26.04	1.81-3.80
		(sandy loam, loamy sand, loam)								
				Stipa comata/Carex heliophila **habitat type**						
10	6.0-7.5	42.0-78.4	20.0-47.0	1.6-16.0	7.5-17.1	1.1-4.1	0.32-3.66	8.4-18.0	10.22-19.21	1.84-4.19
		(sandy loam, loamy sand, loam)								
				Festuca idahoensis/Carex heliophila **habitat type**						
8	6.1-6.7	44.5-67.0	25.0-39.5	6.0-16.0	6.9-14.6	0.8-5.1	0.41-0.78	9.9-19.7	8.70-19.49	2.43-4.14
		(sandy loam, loam)								
				Agropyron smithii/Carex filifolia **habitat type**						
10	5.8-7.6	32.5-50.0	16.5-47.6	12.0-38.6	4.9-13.6	1.4-9.2	0.37-1.99	6.4-45.8	8.41-20.05	2.05-3.89
		(loam, clay loam)								
				Andropogon scoparius/Carex filifolia **habitat type**						
16	6.1-7.8	34.9-78.4	16.0-48.0	5.0-21.6	8.3-20.8	1.5-8.5	0.25-4.52	6.4-11.7	12.9-25.98	1.83-5.63
		(sandy loam, loamy sand, loam)								
				Calamovilfa longifolia/Carex heliophila **habitat type**						
4	5.9-6.4	65.0-90.5	6.9-28.4	2.6-6.6	4.0-7.5	0.9-2.2	0.36-0.54	9.9-16.3	5.40-10.19	1.13-2.60
		(sandy loam, loamy sand, sand)								
				Agropyron spicatum/Bouteloua curtipendula **habitat type**						
3	7.7	47.0-50.4	34.0-35.2	15.6-17.8	7.9-18.3	1.1-4.1	0.33-0.42	6.6-10.9	9.33-21.32	1.86-2.65
		(loam)								
				Agropyron spicatum/Carex filifolia **habitat type**						
2	7.5-7.7	39.2-46.9	48.5-52.0	4.8-8.8	14.8-19.0	2.1-2.2	0.62-0.71	8.2-11.7	17.71-21.72	4.03-5.03
		(silt loam)								
				Artemisia tridentata/Agropyron spicatum **habitat type**						
5	7.0-7.7	43.0-68.0	27.5-36.0	8.0-26.0	9.1-14.3	1.6-2.9	0.34-0.71	8.0-21.0	11.74-17.28	1.52-5.30
		(loam, sandy loam, sandy clay loam)								
				Artemisia tridentata/Agropyron smithii **habitat type**						
7	6.1-7.8	27.5-51.5	23.5-42.5	10.0-36.0	5.7-15.1	2.9-7.8	0.29-0.54	8.2-13.7	9.29-21.43	1.48-2.54
		(loam, sandy clay loam)								
				Artemisia cana/Agropyron smithii **habitat type**						
6	7.0-7.7	31.5-46.0	32.5-46.5	16.0-26.0	6.0-19.2	1.2-6.8	0.33-1.79	7.2-12.3	7.75-26.55	2.05-2.76
		(loam)								
				Juniperus horizontalis/Carex heliophila **habitat type**						
7	6.2-7.1	48.0-73.0	22.0-48.4	2.6-6.0	11.4-19.3	1.8-4.4	0.32-5.51	8.8-11.5	16.12-26.44	4.30-5.46
		(sandy loam)								
				Rhus aromatica/Agropyron spicatum **habitat type**						
5	7.7-7.9	37.5-76.5	11.5-38.5	1.0-24.0	7.2-10.9	0.7-3.7	0.31-0.68	8.9-10.2	9.78-14.18	2.20-3.35
		(loam, loamy sand, sand)								
				Rhus aromatica/Festuca idahoensis **habitat type**						
2	7.0-7.4	55.5-59.5	37.5-41.5	3.0	11.1-11.8	0.8-2.2	0.49-0.59	8.9-11.9	12.49-14.49	3.75-4.10
		(sandy loam)								
				Rhus aromatica/Carex filifolia **habiatat type**						
4	6.9-7.6	58.0-64.0	32.0-37.4	2.6-8.0	12.8-18.1	1.9-3.9	3.20-4.92	7.4-14.5	18.12-24.78	2.43-4.79
		(sandy loam)								
				Sarcobatus vermiculatus/Agropyron spicatum **habitat type**						
3	6.8-7.5	17.0-38.5	15.0-42.0	32.0-68.0	12.6-22.3	7.3-12.7	0.41-0.75	12.3-17.1	21.55-35.41	2.30-3.58
		(clay loam, clay)								
				Sarcobatus vermiculatus/Agropyron smithii **habitat type**						
2	8.0-8.4	34.0-38.0	42.0-44.0	18.0-24.0	4.9-5.2	2.3-4.4	1.06-1.14	10.2-18.0	8.26-10.74	3.12-4.01
		(loam)								

No. of stands	pH	Mechanical analysis % Sand	% Silt (Texture)	% Clay	Exchangeable cations (meq/100 g) Ca	Mg	K	P (ppm)	C.E.C.[1] (meq/ 100 g)	O.M.[2] (%)
					Juniperus scopulorum/Agropyron spicatum habitat type					
4	7.2-7.7	28.0-57.5	29.5-36.5	12.0-40.0	10.1-13.5	3.6-5.0	0.37-0.44	6.6-8.9	14.52-18.94	3.19-4.79
		(clay loam, loam)								
					Juniperus scopulorum/Oryzopsis micrantha habitat type					
3	7.2-7.6	47.0-64.0	27.0-37.0	8.6-17.0	9.0-14.8	4.3-7.2	0.45-0.50	6.6-9.9	13.80-18.15	1.76-4.25
		(sandy loam, loam)								
					Fraxinus pennsylvanica/Prunus virginiana habitat type					
17	6.3-7.5	24.0-71.9	31.0-43.4	2.6-38.0	12.1-22.5	1.2-9.0	0.66-5.68	8.0-30.4	15.14-31.11	2.18-8.12
		(sandy loam, loam, clay loam, sandy clay loam)								
					Populus tremuloides/Berberis repens habitat type					
4	6.1-6.6	57.5-72.4	23.0-32.5	4.6-10.0	9.0-12.4	1.4-4.6	0.90-3.28	13.9-35.3	14.0-19.0	1.72-6.10
		(sandy loam)								
					Pinus ponderosa/Agropyron spicatum habitat type					
3	6.5-7.1	58.0-87.0	10.6-34.6	2.4-7.4	5.7-9.5	2.0-3.1	0.31-0.54	9.2-21.2	9.00-13.14	3.08-4.80
		(loamy sand, sandy loam, sand)								
					Pinus ponderosa/Festuca idahoensis habitat type					
2	5.9-6.7	50.0-73.5	20.1-37.0	6.4-13.0	5.2-7.7	3.1-4.6	0.35-0.60	18.5-21.2	8.65-13.10	3.40-4.98
		(sandy loam, loam)								
					Pinus ponderosa/Carex heliophila habitat type					
3	5.8-6.9	56.5-78.0	16.0-32.1	5.6-11.4	5.0-8.7	1.4-3.7	0.50-4.03	12.1-19.7	8.88-14.13	1.96-3.48
		(sandy loam, loamy sand)								
					Pinus ponderosa/Juniperus communis habitat type					
2	5.6-6.3	75.5	17.5	7.0	4.6-5.5	1.6-1.7	1.31-1.77	17.9-22.5	7.51-8.97	1.88-2.46
		(sandy loam)								
					Pinus ponderosa/Prunus virginiana habitat type					
7	5.7-6.9	42.9-64.0	29.6-41.1	5.0-27.0	2.6-20.0	2.4-5.7	0.30-3.67	13.0-21.5	6.28-26.87	2.52-7.96
		(sandy loam, loam)								
					Shepherdia argentea community type					
11	6.1-7.8	33.9-78.0	20.0-45.5	2.0-20.6	8.2-18.6	2.3-5.4	0.44-1.21	7.0-12.5	13.14-24.67	2.17-6.56
		(sandy loam, loamy sand, sand)								

[1] *Cation exchange capacity.*
[2] *Organic matter content.*

Hansen, Paul L.; Hoffman, George R. 1987. The vegetation of the Grand River/Cedar River, Sioux, and Ashland Districts of the Custer National Forest: a habitat type classification. Gen. Tech. Rep. RM-157. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 68 p.

A vegetation classification was developed, using the methods and concepts of Daubenmire, on the Ashland, Sioux, and Grand River/Cedar River Districts of the Custer National Forest. Of the 26 habitat types delimited and described, eight were steppe, nine shrub-steppe, four woodland, and five forest. Two community types also were described. A key to the habitat types and some of the changes resulting from disturbances of the vegetation also are included.

Keywords: vegetation classification, habitat types, community types

Rocky
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Foreword

During the 1986 Winter Meeting of the Colorado Section, Society for Range Management (SRM), several individuals suggested a need for involvement by the Section in examining the Conservation Reserve Program (CRP) contained in the Food Security Act of 1985. We were primarily concerned about the potential ramifications of the CRP on rangelands and their management during the next one or two decades. These were deemed to be quite significant from both a management and socio-economic viewpoint.

It is important to examine the CRP in terms of its ramifications on soil conservation, agriculture, and society. Next to the Payment in Kind Program, the CRP has the potential to be the most expensive USDA program in history. Nonetheless, Congress, in passing the Act, has recognized the value to the United States of taking erodible land out of crop production. These tax funds are only well spent, however, if much of this land is maintained under a permanent cover after the 10-year rental periods end. Hence, billions of dollars could, and will, be wasted if interested individuals, organizations, and agencies do not use these few intervening years to work towards such an end.

Passage of the CRP resulted from an unlikely coalition of agricultural interests and the environmental movement. The former were primarily concerned about the widespread economic crisis in farming that had resulted from many factors; decreasing land values, low commodity prices, high interest rates, etc. Environmentalists, on the other hand, were willing to support a program that would substantially decrease soil erosion and improve wildlife habitat. It is important to recognize the intrinsic instability of alliances involving groups with little in common, as the CRP is evaluated.

Papers in these Proceedings focus primarily on issues concerning the Great Plains. It is logical to do so for several reasons: (1) early conservation acts were implemented as a result of the Dust Bowl, (2) plowouts of very large blocks of land during the past 10 years were concentrated in the Great Plains, (3) problems precipitating the recent farm crisis appear most severe across Great Plains states, and (4) much of the land base entering the CRP during early signup periods was concentrated in this area.

The opportunities and problems addressed in most papers, however, apply equally to other parts of the U.S. Specific practices, along with recommended species and cultivars to be planted, may differ from those described in this Proceedings. From a farmer's perspective, however, the same basic issues affecting his or her decision to enter the CRP, as well as what kind of permanent cover to plant, apply in every region. Economic and social problems encountered by rural communities impacted by the CRP may well be as common to counties in the Southeast as among those in the West.

The fundamental reason for holding the CRP Symposium and publishing these Proceedings is not to restate historical events or describe the current situation. Their principal importance is in directing a look ahead at the uncertain future, to stimulate thinking about courses of action that will enhance opportunities for achieving the stated goals of the CRP. Secretary Wilson Scaling of the Soil Conservation Service provides focus to the need to foresee shortcomings in legislation and policy in his paper.

Those charged with providing information to farmers and others directly associated with the CRP, as well as those who advise legislators and policymakers, have pivotal roles in the effort to maintain the goals of this Program. Some questions, unfortunately, cannot be addressed if needed research is not funded. Examining research gaps constitutes another way of looking ahead.

Acknowledgement is due one of the Symposium sponsors, the Farm Foundation, for providing a grant to help pay the travel of invited speakers. Many members of the Colorado Section and Denver Office of SRM assisted in the planning and accomplishment of the CRP Symposium, without which this report would not exist. Particularly worthy of mention are Harold Goetz of Colorado State University and William A. Laycock of the University of Wyoming for jointly producing the program. Finally, special thanks are due to Marjorie Swanson, who spent many hours proofreading each manuscript, cross-checking literature citations, and supervising production control, and Karen Omeg for assisting her.

We thank the authors for supplying their papers in electronic form, which helped speed their publication. The opinions expressed are those of the authors, and do not necessarily reflect the opinions or policies of the U.S. Department of Agriculture.

The Conservation Reserve Program: A Perspective

Harold Goetz[1]

Abstract.--The Conservation Reserve Program (CRP) has substantially influenced the nature of agriculture in parts of the United States, including the western Great Plains. It has a potential for even greater influence in future years, depending upon policy and funding. Many of these impacts are still unknown. However, the long term outlook for land use and management under the CRP is positive for those operators who survive the short term perturbations.

It is a great honor and privilege to be here today as a participant in this historic event. This regional symposium is concerned with the many difficult aspects and impacts of the Conservation Reserve Program (CRP). I believe our gathering here to be a benchmark for future decisions and directions this Program will take during the first 10-year period; and undoubtedly, the collective wisdom developed by this assembly of experts will translate into future management policies for all affected natural resources. You are the vanguard for this effort which involves 40-50 million acres of farmland and an unknown number of farm families and businesses.

The CRP is not just another farm program to aid an industry to overcome difficult financial circumstances on a short-term basis. While one of the CRP's consequences certainly is continuity of farmers income, its primary objectives are reducing soil erosion and, thereby, sediment and other pollutants in streams and rivers, protecting fisheries and water treatment systems, preserving soil productivity, providing wildlife habitat, and reducing surplus commodities. While similar farm programs have had some of the same objectives, none have had the potential impact and lasting effects of this program. There are a number of reasons why I believe this to be true.

Previous farm programs have not required, at implementation, a conservation plan which ensures an element of compliance by the landowner if he or she is to share in the revenue derived from the 10-year plan. Another requirement is that only the most erodible land is eligible for this program. Highly erodible land is more likely to remain in permanent cover. It is assumed that there will be no economic incentive to return these lands to annual crop production at the end of the 10-year period, which would restart the cycle of increased soil erosion and add to the continuing surplus of agricultural products. The economic reality of this situation is simply one of low prices and continued financial stress for farmers, continued loss of a valuable natural resource (soil), and the negative impacts on other resources.

An opportunity exists to redirect present land uses to other activities after the 10-year period has expired. The development of multi-species grazing industries certainly must become part of the replacement for the present cereal grain industries. Planting a variety of grasses on the reserve acreages assures the operator of the needed combination of plants to enter into a grazing industry capable of accommodating this approach. Another aspect of this will be the potential development of wildlife habitat that could provide opportunities for fee hunting as another source of income for many operators. Other limited activities which may generate income for some operators include hiking, bird watching, camping, and horseback riding.

The federal government, as advocate for society at large, may be directed to continue this program in perpetuity to ensure the protection and enhancement of the soil and other impacted resources. I believe it is ethical and appropriate that we, as a society, pay the costs of this type of conservation of natural resources. The investment is ultimately more logical and sound than to support policy which can plunder the land through soil erosion, aggravate the surplus situation, thereby reducing farmers' incomes, and generate a repeat of a cycle which has no acceptable or permanent solution.

Perhaps the largest unknown impact of this program is the magnitude of an anticipated negative effect on rural farm communities. The reduction of the demand for agricultural services is, indeed, serious. The immediate loss of cash flow from the purchase of fuels, fertilizer, seeds, etc., and the reduced need for local farm labor and bank loans becomes problematic and may well result in the loss of certain private enterprises that are solely reliant on local sales. On the other hand, for a number of well

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established credit-worthy operators the assurance of a known amount of cash each year for a decade may be the collateral needed to continue to obtain bank loans to operate the portion of the farm or ranch not included in the CRP. This money will also translate into economic activity at the rural level, depending upon the level of purchasing by the operators remaining in business.

The sociological dimension is another aspect: To what extent will communities change in terms of consolidation of farms and loss of families, lack of opportunities to begin or continue farms and associated support businesses, or the inability of operators to form workable partnerships? The very nature of rural economic communities will, perhaps, continue to result in a decline of numbers regardless of the CRP. The decline in farm families is a phenomenon that started after World War II when new technologies allowed for the gradual replacement of intensive farm labor. The Soil Bank Program in the 1950's, the largest land retirement program to date, resulted in a substantially reduced operator pool, and the number of farm operators has continued to decline. Now, the CRP has the potential of further reducing the remaining operators.

Despite the conceivable negative effects from this program, I believe the positive long-term benefits to society will prevail. I have already touched on what I believe will be negative impacts on a short-term basis. The long-term outlook is one of optimism for the future of the farming-ranching industry, for those who survive the initial restructuring from the Program. I believe it is logical to expect larger, more efficient farms and ranches in the future. There will be more cooperative ventures between those who own the land and those who lease from or are in a partnership with the landowners. Managers will be skilled in the application of modern technology such as computers, modeling, remote sensing, and fiscal control. The ultimate objective will be to protect and manage the renewable natural resources in a manner consistent with sustained systems integrity, efficiency, and maximum net dollars.

I believe we, in this assembly, can be a viable and effective force in directing present policy and shaping future policies and programs so that farm/ranch operators, professional resource managers, and the general public support the transition of land use changes to enhance natural resource management for the benefit of future generations.

History of Grassland Plowing and Grass Planting on the Great Plains

W. A. Laycock[1]

Abstract.--Plowing on the western plains started in the 1880s. First attempts to stop erosion by planting grasses came after the Dust Bowl (1930s). During the Soil Bank Program (1956-1969) 14.1 million acres of grassland were planted. These lands were re-plowed along with more than 4.5 million acres of previously unplowed grasslands in the 1970s and early 1980s.

This paper deals with some of the historical aspects of land use on the Great Plains of the United States.[2] The Great Plains, as defined in this paper, are the treeless steppes of North America that lie west of the 98th Meridian and east of the Rocky Mountains and extend from northern Mexico into southern Canada. The climate is semiarid to subhumid. The Great Plains were called "The American Desert" during much of the nineteenth century, a name that was prophetic of the conditions during the drought of the 1930s. Much of this paper will deal with the western and more arid part of the Great Plains nearest the mountains and generally receiving 15 inches or less of precipitation. The native vegetation of this area is dominated by shortgrasses and midgrasses.

The first human inhabitants of the Great Plains were the nomadic and non-agricultural Plains Indians who depended on game for food. The native grazing animals included the bison and pronghorn antelope, both of which were present in large numbers.

Settlement

Spanish explorers come into the plains in the sixteenth century and, during the latter part of the seventeenth century, established missions in southern Texas. However, they had little influence in the Great Plains. Parts of the Great Plains were explored by Lewis and Clark (1803-1806), Pike (1803-1807), and Long (1819-1820). Until about 1830 explorers, fur trappers crossed the Great Plains to get to the foothills and mountains in search of beaver.

Starting in the 1840s, many travellers passed through the plains heading for somewhere else. Travellers on the Oregon Trail followed the Platte and North Platte Rivers in Nebraska and Wyoming starting in 1841. In the late 1840s, the same trail across the plains was used by the Mormons heading for Utah and by the gold miners heading for California. It is estimated that 350,000 people came across this trail in Wyoming from 1841 through 1866 (Dorn 1986).

The cattle industry had become well-established in Texas in the early nineteenth century. Cattle numbers in Texas increased rapidly, but marketing the stock was a problem. Following the Civil War, the railroads were extended west of the Missouri River. The great trail drives taking Texas cattle northward began in 1876 when cattle were driven to the railhead at Abilene, Kansas, to be shipped to Chicago and other eastern cities. As the railroads continued westward, so did the shipping points. Between 1867 and 1880, over 4 million cattle were trailed north to the railroads in Missouri and Kansas and shipped to the East (Webb 1931).

The first cattle came to the western part of the northern plains in 1866 when Charles Goodnight and Oliver Loving brought 1000 cattle through New Mexico on the Goodnight-Loving trail and sold them to John Wesley Iliff near Greeley, Colorado. The 1860s and 1870s was a period when large ranching operations were formed through the use of foreign capital (mostly English and Scottish) and "free" grass on the public domain lands. In northeastern Colorado, Iliff owned only 15,000 acres but, by virtue of controlling access to water, he dominated the whole northeastern part of Colorado and ran 35,000 cattle. The Prairie Cattle Company, a British company, controlled over 5 million acres in Colorado, New Mexico and Oklahoma and owned

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[2]*The early history was drawn largely from McGinnies, W.J., and W.A. Laycock (In Press), The Great American Desert--Perceptions of Pioneers, The Dust Bowl, and The New Sodbusters, a paper presented at the Arid Lands Research Development Conference in Tucson, Arizona in October, 1985.*

140,000 cattle (Steinel 1926). There were many other such ranching operations throughout the Great Plains. Cattle numbers in the Great Plains states increased from 1.1 million in 1870 to 4.4 million in 1880 to 8 million in 1886 (U.S. Senate 1936).

Mild winters had prevailed on the plains in the 1860s through the mid 1880s when this rapid expansion took place. However, the winter of 1885-86 on the southern plains was extremely severe and the following winter was also quite severe on the northern plains (Mitchell and Hart 1987). During these two years, hundreds of thousands of cattle either froze or starved to death. This, coupled with drought and a drastic decline in cattle prices, helped end the days of the vast cattle empires on the plains.

Another factor which influenced the decline of the cattle industry was the arrival of homesteaders in the western part of the plains. Congress had passed the Homestead Act in 1862. It allowed a person to take possession and farm 160 acres. The better lands in Iowa, Missouri, Kansas, Nebraska and other eastern plains states were homesteaded first. There, 160 acres was sufficient to make a living. In the western plains much of the land and the climate were not suited to farming, and 160 acres was insufficient to support an individual farmer and this family. However, large numbers of homesteaders started to reach the western Great Plains by the mid 1880's.

The transcontinental railroad across Nebraska and Wyoming was completed in the late 1860's. In the 1870s and 1880's other railroad lines were pushed into many parts of the western plains. Most of the railroads received a government subsidy in the form of land. The railroads were anxious to sell this land to settlers in order to raise capital and to provide a steady passenger and freight revenue. Land was also available for the settlers to homestead. To entice settlers to move to the Great Plains, it was first necessary to dispel the myth of the "Great American Desert." Promoters, called "Land Boomers," made extravagant claims about the productivity of these lands. They claimed that "rain follows the plow"; i.e., as soon as people started farming, more rains would come. Reports of exceptional crop yields (obtained during very favorable years) were widely reported in the Eastern press. Such high yields often occur immediately after sod is broken because of the initial availability of nutrients.

By 1890, 6 million people were living on the Great Plains, most who had come after 1886. Between 1880 and 1899, 104 million acres on the plains were plowed for crop production (U.S. Senate 1936). Wheat grown under dry land farming techniques has been the primary crop since the 1890's.

Shantz (1956) reported that, by 1908 in eastern Colorado, only 13% of the land had been plowed. When he again surveyed this same area in 1949, 96 percent of the land had been plowed. Most of the new plowing was done from 1915 to 1925 to grow wheat needed during World War I and the economic expansion that followed. It was also during this period that large-scale mechanization came to the wheat-growing areas of the United States. This permitted an individual farmer to raise crops on much more land. All of this plowing had a major effect on the severity of the dust storms during the Dust Bowl period.

The Dust Bowl, 1931-1936

The history of the Dust Bowl has been well documented. Of particular interest are recent books by Worster (1979) and Hurt (1981). Hurt (1981) pointed out that there were many severe dust storms before those of the 1930's. Dust storms were reported in 1830, 1854, 1860-1864, 1874-1878, 1886-1888, 1892-1893, 1895, 1901-1904, and 1912-1914. Shantz (1956) observed that, while there had been dust storms, there was no Dust Bowl until the native sod was destroyed by the plow.

In the United States, starting in 1931 and continuing until 1936, precipitation throughout the plains was extremely low. In some years the native grasses did not even green up and crops routinely failed. By 1933 almost any wind was creating dust storms from fields bare of crops (Hurt 1981). The major dust storms occurred in 1934 and 1935, some of which reached the east coast and out over the Atlantic Ocean. One such storm in May 1934 was cited by Hugh H. Bennett, first Director of the Soil Conservation Service, as a turning point in arousing public awareness of the problem:

> "This particular dust storm blotted out the sun over the nation's capital, drove grit between the teeth of New Yorkers, and scattered dust on the decks of ships 200 miles out to sea. I suspect that when people along the seaboard of the eastern United States began to taste fresh soil from the plains 2,000 miles away, many of them realized for the first time that somewhere something had gone wrong with the land.... it took that storm to awaken the nation as a whole to some realization of the menace of erosion."

These dust storms spurred a formerly apathetic government into action. The Bankhead-Jones Act was passed in 1935, one portion (Title III) of which authorized the government to buy submarginal land that was not capable of supporting a family. Land Utilization Projects were established throughout the western part of the Great Plains as models for proper grassland agriculture. Many of these plowed lands were seeded to perennial grasses while others were allowed to return to a grass cover naturally through the process of secondary succession. These Land Utilization Projects were administered by the newly created Soil Conservation Service from 1938 until 1954. In 1954 most of these lands were turned over to the Forest Service and are now known as National Grasslands.

The New Sodbusters

During the period following the Dust Bowl, conservation practices were developed and put to use. In the 1940's, a decade of generally favorable precipitation, some additional land was plowed for wheat production, a result of the needs of World War II and the desire to take advantage of the high wheat prices in the post-war period. An intensification of plowing of previously unbroken grassland began in the mid 1970's after the historic Russian wheat sale of 1972 and continued into the 1980's.

National attention of such activity did not come until the spring of 1982 when a Canadian farmer purchased approximately 15,000 acres of rangeland in Weld County in northeastern Colorado and proposed to plow it (Steinmark 1983). The county commissioners, worried about the consequences, first tried unsuccessfully to get the state to intervene, then finally passed an emergency ordinance prohibiting plowing of grassland that had not been plowed in the past 5 years without a permit. Unfortunately, the 15,000 acres in question had already been plowed by the time the ordinance was passed.

This particular plowing incident and the legal action by Weld County drew national television and newspaper coverage and prompted widespread concern in Colorado and other states. Several other counties in Colorado and at least one county in Montana have adopted laws patterned after the Weld County legislation to try to prevent unwise destruction of native grassland. The Weld County incident was only one example of what had been happening in the previous years throughout eastern Colorado and in other plains states such as Montana (Walcheck 1983) and Nebraska (Aucion and Pierce 1983).

Approximately 4.5 million acres of previously unbroken grassland have been plowed during the recent past in the central and northern Great Plains (table 1). The greatest amount of plowing has been in Montana with 1.8 million acres plowed between 1977 and 1982. Newly plowed land in North Dakota (849,000 acres), South Dakota (750,000 acres), and Colorado (572,000 acres) make up the bulk of the additional area plowed (Laycock and Lacey 1984). Much of this was in land capability classes IVe, VI and VII.

In 1983, by far the greatest amount of grassland plowing activity was in Montana. The total acreage plowed in 1983 is not known, but was estimated to be 250,000 acres. Some very extensive areas plowed in solid blocks received widespread publicity. For example, one operator plowed a large part of the 50,000 acre Crow Rock Ranch in Garfield and Prairie Counties, and another plowed about 25,000 acres of 2 ranches in Petroleum County. Much of this plowing was done in solid blocks, miles on a side, filling in gullies and waterways (Walcheck 1983, Crummett 1983). By 1984 declines in land prices and low wheat prices had stopped much of the plowing, at least on such a large scale.

Table 1.--Area of previously unplowed grassland in the northern and central Great Plains, plowed in the 1970's and early 1980's. Figures are estimates from the Soil Conservation Service in each state.

State	Area (thousand acres)
Colorado	572
Kansas	15
Montana	[1]1,842
Nebraska	400
North Dakota	849
South Dakota	750
Wyoming	71
Total	4,449

[1]Land plowed through 1982. An additional 250,000 acres was estimated to have been plowed in 1983, but cannot be substantiated.

Very little grassland would have been plowed if there were no economic incentives to do so. Of primary importance has been the depressed state of the cattle industry. Cattle prices have been and remain low, and many cattle raisers have lost money on their operations for a number of years. Until recently, a great many ranchers had stayed in business only by using steadily increasing land values as collateral for loans for operating capital.

The loan value of the land stimulated some of the plowing (Huszar and Young 1984) because farm land was worth two to three times as much per acre as rangeland with little regard for the long-term productive capacity of the land or the erosion hazard. In fact, some plowing apparently was forced by banking or agricultural lending organizations insisting that certain lands be plowed in order to qualify for loans. Some of this type of plowing to increase land values was done by individual ranchers or farmers, but more often it was done by speculators, at least in the late 1970s and early 1980s. In the last several years, drastically decreased land prices have temporarily taken the speculators out of the picture.

In addition to the economic factors discussed above, government agricultural support programs have played a major role in grassland conversions (Walchek 1983). Crop price supports, crop insurance, disaster payments, Farm Home Administration loans, land set-aside payments such as the Payment in Kind program (PIK), and storage loans enhanced the expected returns from grasslands converted to crop land and accelerated the plowout. It is at these federal subsidies that Sen. William Armstrong (R-Colorado) aimed his "sodbuster" bill, which passed the Senate in 1982 and again in 1983 but failed to pass in the House in both years. Different versions of the "sodbuster" bill passed both houses of Congress in 1984. However, the conferees could not agree and the legislation died. The Food Security Act (FSA) of 1985 contained "Sodbuster" and "Compliance" features and also provided for a "Conservation Reserve" which would pay farmers for putting highly erodable land back to pasture or other permanent vegetation.

Efforts to Revegetate Plowed Lands

The first major effort to replace perennial grasses on plowed land on the Great Plains came after the Dust Bowl. By 1951, 0.9 to 1.1 million acres were seeded on the almost 6 million acres of the Land Utilization projects in 12 states (from undated and unpublished file report "Policies Regarding Conservation and Development and Use of Land Utilization Project Lands Administered by the Soil Conservation Service"). No record was found of the species used or success of the seedings. Entire Land Utilization Projects were put under proper grassland management and the lands have been retained in Federal ownership preventing any replowing. Except for those in Montana, the Land

Utilization lands were turned over to the U.S. Forest Service in 1954 and have been administered as National Grasslands (table 2).

Most information concerning the drought of the 1930's has focused on the Great Plains of the United States. Gray (1967) published a book "Men Against the Desert," which outlined what happened in the Palliser Triangle of Alberta, Saskatchewan and Manitoba in Canada. The drought started earlier in this area than in much of the United States and crops first failed in 1929. The drought prevailed into 1936 with record high temperatures recorded in 1931, 1934, and 1936. The Prairie Farm Rehabilitation Administration (P.F.R.A.) was formed in 1935 to rehabilitate the land and put it back into grazing use. At least one million acres were seeded to perennial grasses, mainly to crested wheatgrass *(Agropyron cristatum)*. The seeded and intermingled natural prairie area were fenced into "community pastures." This fenced land totaled 1.0 million acres by 1942, 1.4 million by 1948 and 2.3 million by 1965. These lands are still administered and managed by P.F.R.A., and grazed by local ranchers organized into cooperatives.

The use of shelterbelt planting constituted another approach to prevent erosion during and after the drought of the 1930's on the Grain Plains. In 1934 the federal government proposed to plant windbreaks in a strip 100 miles wide south from the Canadian border to Oklahoma. The first shelterbelt was planted in Oklahoma on March 18, 1935 (Anonymous 1986). By 1942, when much of the effort was completed, 223 million trees had been planted on 30,000 farms and ranches. (Anonymous 1986). These shelterbelts stayed in place, for the most part, until the mid-1970's when farm and machinery size expanded and the shelterbelts began to be viewed as "in the way" of both machinery and the new center-pivot sprinklers. The specter of an another drought had been forgotten or disregarded, and a great many of the shelterbelts were removed and maintenance of many of the other was discontinued. Thus, the trees and shrubs that had been planted with government subsidies were removed to grow more crops which were subsidized by the same government.

Table 2.--Area of Land Utilization Lands which became National Grasslands (from Rowley 1985).

State	Area (thousand acres)
Montana	[1]1,900
North Dakota	1,105
South Dakota	864
Colorado	612
Wyoming	573
New Mexico	134
Texas	117
Kansas	107
Oregon	103
Nebraska	94
Idaho	48
Oklahoma	47
Total	5,704

[1]Lands in Montana were turned over to the USDI Bureau of Land Management. All other lands became National Grasslands administered by the USDA Forest Service.

Table 3.--Land area in Soil Bank Program in the Great Plains at its peak (1960-1961) and total cost (1956-1969).

State	Land area (Thousand acres)	Total cost (million $)
Colorado	1,300	91
Kansas	1,450	136
Montana	630	46
Nebraska	880	72
North Dakota	2,705	209
Oklahoma	1,494	123
South Dakota	1,822	140
Texas	3,667	299
Wyoming	125	8
Total Great Plains	14,073	1,124
Total U.S.	28,661	2,477

The first major effort to get perennial cover planted on plowed private land was the Conservation Reserve Program established in 1956 under the Soil Bank Act. The primary purpose of the program was to divert land from crop production. The secondary purpose was to establish and maintain protective vegetative cover (trees, perennial grass, etc.) on the land taken out of crop production (undated and unpublished file report, Soil Conservation Service "Final Report, Conservation Reserve Program, Summary of Accomplishments, 1956-1972).

The Soil Bank was a voluntary program. Each participating farm signed a contract to withdraw a designated area of cropland from production for 3 to 10 years. Other agreements were to; (1) comply with any acreage allotments, (2) reduce the total cropped acreage by the amount placed in the reserve, and (3) provide and maintain approved conservation cover on the reserve land. The farmer was eligible for cost sharing for establishment of the conservation cover and received annual rental payments to compensate for the loss of income on the acres retired.

At the peak of the program in 1960 and 1961, there were more than 306,000 farms with approximately 28.7 million acres under contract (table 3). About half of these acres (14.1 million) were in the Great Plains and most of these were planted to perennial grass. Total cost of the program was $2.48 billion for rental payments and $162 million cost sharing for establishment. The average annual payment was $11.85 per acre. and the average total payment for the life of the program was $86.43 per acre. All contracts had expired by the end of 1969.

It appears to be debatable whether the primary purpose of the Soil Bank, i.e., to divert land from crop production, was achieved. Figure 1 shows the acreage enrolled in the Soil Bank Program and the total acreage of wheat in the Great Plains. It is assumed that most of the land put into the Soil Bank in the Great Plains were wheat lands. The Soil Bank does not appear to have

resulted in a substantial drop in the acres of wheat planted in the plains. The drop in wheat acreage in 1957 may have resulted more from a separate voluntary Acreage Reserve Program in 1956-58 that paid farmers not to grow crops. This Acreage Reserve Program idled about 11 million acres on the Great Plains in 1957. There were similar cropland set-aside programs in 1969-1972 for 12-20 million acres each year. These tended to reduce wheat acreage during the period when the Soil Bank contracts were expiring.

The secondary purpose of the Soil Bank, i.e., to establish and maintain protective vegetation, also failed in the long run, at least on the Great Plains. A fairly dramatic increase in wheat acreage starting in 1973 resulted in most Soil Bank lands being plowed and was at least partially a response to prices. Wheat was selling for about $1.80 per bushel in 1972. A large wheat sale to Russia pushed prices to more than $4.00 a bushel in 1973 and 1974. By 1977 prices had fallen to $2.30 per bushel and this, coupled with new set aside programs in 1978 and 1979, again reduced wheat acreage. The drop in acreage in 1983 (fig. 1) appears to be a result of the PIK (Payment in Kind) Program.

It appears that the Soil Bank Program was successful as a conservation measure only during the life of the contracts. Although data are not available, experienced observers have indicated that, on the Great Plains, almost all of the cropland planted to grass in the Soil Bank Program were plowed again in the early 1970's or later. Thus the $2.6 billion spent ($86 per acre under contract) was not effective as a long-term conservation measure. Although much more difficult to determine, it also appears that the Soil Bank had little immediate or long term effect on the reduction of acreage planted to wheat.

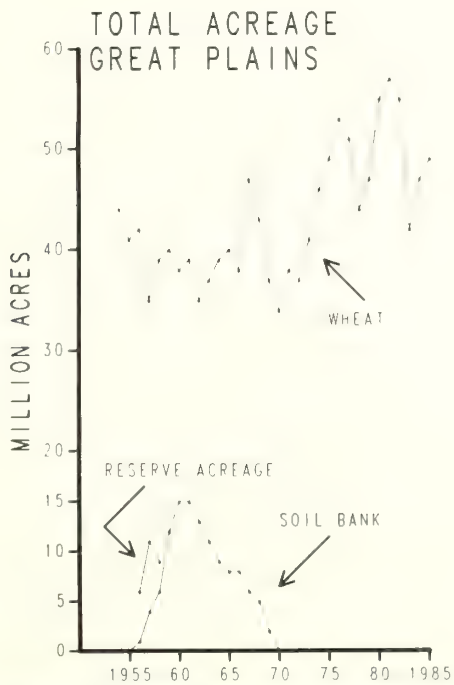

Figure 1.--Total acreage of wheat on the Great Plains and amount of land in the Soil Bank, 1956-1969.

Table 4.--Great Plains range and pasture lands identified as having high and medium potential for conversion to cropland in the next 10-15 years (Hexem and Krupa, 1987).

State	Area (thousand acres)
Northern Plains (ND, SD, NE, KS)	20,397
Southern Plains (TX, OK)	25,927
Plains "Fringe" (MT, WY, CO, NM)	11,410
Total	57,734

Conservation Reserve--1985

The Conservation Reserve Program (CRP) of the Food Security Act of 1985 provides for up to 45 million acres of highly erodable land to be planted to permanent cover. Other papers in this proceedings will discuss the CRP in detail. It is important to note that this program is very expensive (average cost of a Conservation Reserve contract will be $450-500 per acre as compared to the $86 paid during the Soil Bank program). In the western Great Plains this is many times what the land could be purchased for at the present time.

Will the current CRP succeed where the Soil Bank failed and result in permanent retirement of these erodable lands? The Sodbuster and Compliance provisions of the 1985 FSA should help accomplish this. The main question is whether USDA policy and Congressional legislation will remain resolute in preventing re-plowing of these lands when CRP ends. Past history does not provide much encouragement that such resolve will prevail. We seem to be very willing to modify our conservation laws and policies to take advantage of short-term economic opportunities.

One indication of conflicting and potentially harmful policies is the publication of a study by the USDA Economic Research Service on the amount of land not currently cropped that could be converted to crop use (Hexem and Krupa 1987). They reported that about 35 million acres in the United States have a high potential for conversion to crop use and 117 million more acres have medium potential for conversion over the next 10-15 years. They identified 57.7 million acres of range and pasture land in the Great Plains states with a medium or high potential for conversion to cropland (table 4). Although the range and pasture land was not identified by land class, from other figures presented it can be concluded that much of the land identified for possible conversion is in land capability classes IV through VIII.

It appears that some serious policy conflicts are occurring and will continue in the future. Identifying more than 57 million acres of range and pasture land in the Great Plains as having potential to be plowed in the next 10-15 years at the same time that 45 million acres are being taken out of crop production in the Conservation Reserve Program in the entire U.S. does not bode well for a future consistent policy either by USDA or Congress. Plowing new land at the same time or following retirement of substantial amounts of erodable land would negate the effects of a very expensive conservation program.

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Rationale and Legislation for the Creation of the Conservation Reserve Program

E. Wayne Chapman[1]

Abstract.--America's farmers and ranchers provide basic and necessary products fo life on this hungry planet. However, in the 1980s the family farm is caught in the tightening jaws of increasing costs and decreasing prices to the extent that soil conservation practices have often become economically infeasible. The Conservation Reserve Program (CRP), contained in the 1985 Food Security Act, provides the necessary incentives to take highly erodible and eroding land out of crop production, and place it under permanent cover. The CRP, as passed, represented compromises between the Congress and various interest groups.

I love to travel this great land of ours, especially here in the West. I envy you who live out here. I was reminded of what I am missing last month as my wife and I drove through Wyoming and Montana and counted more antelope than cars for several hundred miles.

Shag and Billy are two cowboys that Stan Lynde from Red Lodge, Montana have created and used in his cowboy cartoon book, Grass Roots. Stan was gracious enough to give me permission to use some of his cartoons to help illustrate my talk. I bought Stan's book in Billings, Montana last month while attending the National Soil Conservation Society of America Convention.

I asked Stan if his book was available here in Denver and he said he didn't think so, but added that he would be glad to send you an autographed copy if you wanted to order one from his Red Lodge, Montana address.

In one cartoon, Shag says, "It's not the things I don't know that worry me..It's findin' out I've been wrong about all them things I thought I knew."

There is a lot I don't know about the events that led up to the Food Security Act (FSA) of 1985 and I am sure some of the things I think I know may not be the fact but I am glad to share what I think I know.

Stan not only tells a good story with his pictures but I like the story he paints with the short commentary he includes with each.

For example, in a range cook wagon scene with Billy saying, "It sure is a crazy world, Shag, when almost a third of its people are starving!," Shag replies, "Yep..an' when the world's best farmers a' ranchers can't even make a living!"

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For this picture Stan says, "The way of the world is filled with irony, and it doesn't take a great thinker to see that a lot of life just doesn't make much sense."

By all that's fair and just, America's farmers and ranchers should be among the world's most highly paid and respected people. Their products are basic and necessary for life on this hungry planet and their industry and dedication have led to ever-increasing production on ever-decreasing acreage, and against the perils of predators, weather, crop disease, insects, imports, inflation, and bureaucrats.

Film stars and football players are better paid and honored by far, but you can't eat a movie--and astroturf makes a poor salad.

One cartoon depicts a bear along with Billy and Shag on horses. Billy says, "Holy smoke, Shag! That's a grizzly bear!" Shag replies, "Yep..He belongs to one O' them endangered species..like the family farm." Stan says for this drawing, "Nature's ecosystems are in a state of delicate balance that man, with his arrogance and technology, can easily damage and destroy. But endangered species are not limited to the passenger pigeon, trumpeter swan, and grizzly bear; even institutions can quality."

To Shag, the family farm is such an endangered species, and threats to its existence may include inflation, bureaucracy, land developers, and foreign imports.

Today I plan to discuss why I believe such a strong Conservation Provision was included in the 1985 FSA that authorized the Conservation Reserve Program (CRP). What were the factors that came together to cause this to happen even with such a national debt facing our Nation and a farm economy on the ropes?

Then I will explain a little about what I saw happening from my position on the House Agricultural Committee staff in 1985 while the Bill was developing. Finally, we will examine how the

CRP fits in with the Sodbuster, Conservation Compliance, and Swampbuster parts of the Bill, and what, in addition to putting the highly erodible land in the CRP, farmers will need to do to stay eligible for Farm Program benefits.

The short version of my talk can be summed up in a few words. Congress passed a strong conservation provision in the 1985 FSA because they perceived soil erosion was a serious national menace and they wanted to help farmers do something about it.

They recognized that we have a situation, not necessarily the fault of the farmers, where farmers are hurting and our soil and water, our basic natural resources are hurting. They believed that the CRP would help meet the need of both the farmers and the soil and water resources.

On February 6, 1985, I was just getting into my assignment with the staff of the House Agriculture Committee. I clipped a picture from the USA Today newspaper that showed farm foreclosures had increased by 68 percent from 1982 to 1984, from 844 to 1,422, and as you know the picture hasn't gotten a lot better since.

Back to Stan Lynde's book, Grass Roots. Shag is at a bank; the banker says, "Well..yes, Shag..the bank might consider granting you a loan. What do you want the money for?" Shag says, "I'd like T' buy me some postage stamps, Bob.")

The first six months of 1985 Agriculture committees of both the House and Senate was dominated by farm credit concerns. It was really heart rendering to hear the farm families who were testifying at the hearings tell how they were losing the farm which had been in their family for generations. Even the movie industry was recognizing the widespread hardship in the agricultural sector. Three separate movies were showing during 1985 on the subject and the stars of these movies - Jane Fonda, Jessica Lange, and Sissy Spacek all appeared before the Agricultural committees on behalf of the farmers. Needless to say the hearing rooms were packed when they showed up and several more TV crews were on hand.

One of the things I remember from a political science course was that it usually takes five or more years from the time the need for a law is recognized until it becomes a law. This was true for The Soil Conservation and Domestic Allotment Act of 1935, Public Law 74-46, which is the same basic law the Soil Conservation Service operates under today. The law has never been amended. Let's look back to what was happening prior to its passage, our Nation's first real crack at tackling the soil erosion problem.

In 1928, a young soil scientist, Hugh Hammond Bennett of North Carolina, persuaded USDA to publish Circular 33, Soil Erosion, A National Menace. Congressman James P. Buchanan of Texas held hearings on the erosion menace, and, as a result, in 1930, the first federal money to begin a national survey of soil erosion damage was made available. It was $160,000, to be used by USDA to investigate "the causes of soil erosion and the possibility of increasing the absorption of rainfall by the soil in the United States" (Sampson, 1981).

The person who wrote this statement of purpose was pretty perceptive. He or she recognized that the way to stop soil erosion is to increase the absorption of rainfall by the soil. What happens when just about any conservation practice is applied? The grass and trees we plant on CRP land increase absorption. Conservation tillage, contour farming, and terraces all increase absorption.

The erosion survey confirmed there was a real erosion problem. In 1933, five years after the study was initiated, the Soil Erosion Service was established. Two years later, with a little help from a good dust storm, that may have started just east of Denver, the Soil Conservation Service was established along with a national policy on soil erosion. The policy, as stated in Public Law 74-46, was "... to provide permanently for the control and prevention of soil erosion, and thereby, to preserve natural resources, control floods, prevent impairment of reservoirs, and maintain the navigability of rivers and harbors, protect public health and public lands, and relieve unemployment..." (Burns, 1985).

Why, after more than 50 years with a law that says it is our policy to control and prevent erosion and with the billions of dollars poured into soil and water conservation programs, haven't we solved the erosion problem?

There is a funny thing about nature; it is not the least bit impressed by man's policies and laws. The simple law of nature is that as long as we plow and plant, soil will erode on the steep slopes every time it rains unless it is protected by a good conservation cover. On the steeper slopes, cover alone is not adequate and the slopes must be broken by terraces, strip crops or some other means. It doesn't matter that we solved the erosion problem on the field 30 years ago, 20 or 10 years ago or even just last year. If a new operator takes over or the same operator fails to continue the conservation system, when it rains or the wind blows the soil will erode again.

However, I would like to tell you a personal story that I think illustrates that erosion can be controlled over a long period of time. Last year in August, during the second CRP signup, Don Gillaspie, State Resource Conservationist for the SCS here in Denver, invited me to come out to see first-hand how the CRP was being implemented. My wife and I used that occasion to drive through Vernon, Follett, and Spearman, Texas where we had worked with the SCS. It had been 27 years since we had been to Follett, a town of about 500 people in the very northeast corner of the Texas panhandle. On the way to Follett we drove by Harold Schoenhal's farm. In 1957, Harold was just taking over the operation of the farm from his dad. The previous year, a new law had established the Great Plains Conservation Program (GPCP). I helped Harold write a conservation plan which he used to apply for one of the first Great Plains Conservation Program contracts in the Nation. We started to implement the plan when in 1959 I was transferred, so I hadn't gotten to see the plan fully implemented. As we drove by the farm I was surprised that I remembered the details of Harold's conservation plan as if it had been yesterday. Thirty years ago There was a tremendous erosion problem on the farm.

We planned to plant grass on some of the steep land that sloped into a pasture that had a large draw in it. We planned terraces on the sloping cropland and agreed on contour farming and improved residue and range management to increase cover on the land and increase absorption. We even planned to plant red cedar, Russian olive and other shrubs for wildlife habitat at several spots near windmills.

Harold's name was still on the mailbox and, yes, the terraces and the grass on the slopes were still there. The red cedars, now 30 years old, looked real good. He is continuing to carry out his plan. That made me feel good.

I thought how lucky I am to have been a part of helping influence farmers and ranchers like Harold to conserve their land. I believe the answer to long term erosion control in this country is to convert the owners and operators of the land into practicing conservationists like Harold Schoenhals.

Unfortunately, many farmers have not been practicing good conservation. There are a lot of reasons and excuses given for not doing so. To me the reason is they have not yet adopted a conservation ethic.

Perhaps the most accepted excuse for the excess erosion today is that, when prices of farm products shot up in the 1970's, farmers responded by plowing "fence row to fence row" and plowed out land they should not have. We often like to blame then Secretary of Agriculture Earl Butz for the great plow out. This plow-out resulted in an increase in harvested cropland from 335 million acres in 1972 to 391 million in 1982, an increase of 56 million acres (Burns 1985). That increase amounted to more than the present 40 to 45 million-acre CRP goal. But farmers didn't need Mr. Butz to tell them to plow out those acres; I suspect they would have done it even if he had told them not to.

The point is, highly erodible land was taken from permanent covers of grass and trees, and planted to soybeans, wheat, and other crops; moreover, much of it isn't being farmed properly to prevent excessive erosion. Then, prices dropped and farmers had no extra money to put into soil and water conservation practices. Farmers were hurting and their land was hurting.

Hence, it may well have been the accelerated erosion spawned by plow-outs during the 1970's which is the real reason for the CRP. Many of us who have spent our careers in soil and water conservation, and who have seen scenes of erosion too often following rain and wind storms, would like to think that we finally convinced enough people that we still have a serious erosion problem and we need to do something about it.

The similarities of events that led up to the passage of the Soil and Water Conservation Act of 1935 and the 1985 Act are striking. Remember, 1930 a national erosion survey was commissioned and five years later the 1935 Soil Conservation Act was passed.

A new national erosion survey, the National Resource Inventory (NRI) was completed in 1980, five years before the 1985 FSA. It was published in March 1981. In 1977, Congress had passed the Soil and Water Resources Conservation Act (RCA). This legislation required USDA to set up a formal process to; (1) appraise on a continuing basis the soil, water, and related resources on nonfederal land, (2) develop programs for furthering conservation, protection, and enhancement of these resources, and (3) annually evaluate program performance.

Neal Sampson, in his book "Farmland or wasteland, a time to choose," (1981) said, "The RCA appraisal paints a stark picture: The soil and water resources of the Nation are being wasted at a rate unparalleled in recent times." He went on to point out, "... the Carter administration established the National Agricultural Lands Study (NALS) in mid-1979 as an 18-month effort to answer several important questions about the nation's farmland supply."

The NALS had also been commissioned by the House of Representatives Subcommittee on Conservation, Credit, and Rural Development. It was directed by two very respected and able men, Norman A. Berg, former Chief of he Soil Conservation Service, and Robert J. Gray, Director of Policy Development for American Farmland Trust (AFT) and former Executive Director of the NALS. The stage was set for credibility and ownership of the findings from the study by the scientific community, the Administration, and Congress. This study, conducted by the AFT, concluded that soil erosion on U.S. cropland could be substantially solved, at a reasonable cost, within the decade.

They made 23 specific recommendations. Recommendation 10 was that the 1985 Farm Bill should contain legislative authority for a long-term conservation reserve. Therefore, the RCA, the NRI, and the NALS helped produce a greatly increased awareness of resource problems.

A conservation coalition of 20 to 25 major conservation organizations was formed and headquartered in Washington, D.C. Robert Gray and Norman Berg are leaders in this somewhat unique coalition. It included organizations such as the National Association of Soil and Water Conservation Districts and the Sierra Club, who just a few years ago talked to each other only in the court room trying to settle law suits over "channelization" issues. During the hearings on the 1985 Farm Bill they spoke as one voice in favor of a strong conservation title in the Bill.

Let me talk a little about my year on Capitol Hill. This assignment, which turned out to be one of the most interesting of my career, began in December 1984. The Soil Conservation Service and other Federal agencies participated in a training program which sends a few of its employees to Capitol Hill for up to one year to gain a better understanding of how the laws we are asked to implement are enacted. The participating agencies continue to pay the employees salary and the legislator gets the services of a technically trained staff assistant in return for furnishing the training and administrative support. The participant interviews with Senators and Congressmen and may serve on personnel or committee staff. I chose to work for the House Agricultural Committee staff.

I guess the thing I learned that was of most interest to me was how the committee and subcommittee system works. In the Senate, the committee is called the Agriculture, Nutrition, and Forestry Committee and is chaired this year by Senator Patrick Leahy of Vermont. In 1985, it was chaired by Senator Jessie Helms of North Carolina. The ranking minority member this year

is Senator Robert Dole of Kansas. In 1985, Senator Edward Zorinsky from Nebraska was the Democratic ranking minority member.

On the House side the committee is called, simply, the Committee on Agriculture and is chaired by Congressman E de la Garza of Texas with Congressman Edward Madigan of Illinois being the ranking minority member. Both of these men were also there in 1985 and I was hired by Congressman Madigan since I worked with the minority members of the staff.

But the real nuts and bolts of legislation are put together, not in the committee, but in the various subcommittees. To influence what the legislation says, the most important people to work with are the subcommittee chairmen and ranking minority members of the subcommittee and the staff people who work for them.

There were about 60 separate farm bills introduced in 1985. I nearly ran myself crazy trying to keep up with these until one of the staff asked me why I was bothering. He told me the only bill that we needed to worry about was the one introduced by Congressman Ed Jones, the chairman of the subcommittee responsible for conservation legislation. He had introduced a bill the previous year which passed the House and reintroduced it again in 1985.

This sets the stage for another factor which I think had a lot of influence on the outcome of the conservation title of the Bill. It has to do with people in the right place at the right time.

In 1982, Peter Myers became the first Chief of the Soil Conservation Service not to have come from the ranks of SCS. He was still Chief of SCS when I began my Legislative Fellow training with the House Agricultural Committee, having selected me for the assignment. As Chief of SCS he was, of course, very interested in the conservation part of the Bill. By then he had traveled all over this land and seen the erosion problems first hand. He also brought a farmer's perspective to the job and noticed those farms where erosion was being controlled.

Another incident I think he remembered concerned the 1983 Payment in Kind (PIK) program. When this program was being planned, he and Bud Rank, then Administrator of the Agricultural Stabilization and Conservation Service (ASCS), had met and decided to try to beef up the conservation requirements of the land that would be diverted under the PIK program. I helped develop the instructions that were sent to the SCS State Conservationists. Basically, they said the SCS State Conservationists would approve the amount of cover that would be acceptable on the diverted land. If the residue from the last crop was not managed so it would be adequate to control erosion, a cover crop should be planted. The farm interest groups affected by this requirement got busy, and working with their Congressmen and Senators, caused the Secretary to relax the treatment requirement.

Midway during 1985, after being elevated to the position of Assistant Secretary for Natural Resources and the Environment, Mr. Myers took these concerns and knowledge with him. He was in a position to speak for the Secretary and influence the Administration of the need for a strong Conservation Title. He and Secretary Block met several times with the committees and supported the CRP.

I found myself being used as a communication link between the House Agriculture Committee and Mr. Myers on issues that would arise on which the committee wanted to know the Administration position. Having worked closely with Mr. Myers in the SCS, I felt at ease in picking up the phone and discussing these issues with him.

The major issues resolved around the amendments that were made to the Jones' Bill on the House side and the elms' Bill on the Senate side. The major amendments are outlined below.

Agriculture Committees

Senate

Agriculture, Nutrition and Forestry

Chairman: Patrick Leahy - VT

Ranking Minority Member - Robert Dole - KS

House

Chairman: E de la Garza - TX

Ranking Minority - Edward R. Madigan - IL

The bill that Congressman Jones introduced did not include what we have come to call the Conservation Compliance or Swampbuster provisions; these were added. There was a long debate over the look back time period for the Sodbuster provision and it was changed from a 10-year period to a 5-year period.

An amendment was added to encourage, where practical, 12.5 percent of the CRP acres be planted to trees.

One day a staff member came to my office and said, "Wayne, I need your help in wording an amendment to keep Christmas trees from being grown on CRP land. My Congressman has a lot of commercial Christmas tree growers and they are on his back to see that they don't have this unfair competition." He showed me his amendment and it said that no trees could be harvested on CRP land for a period of 20 years. Well, this wouldn't work too well in the south where they would be able to start harvesting pulp wood shortly after the 10-year CRP contract expired. So we reworked the amendment to be a little more straightforward and just prohibit the planting and harvesting of Christmas trees. About that time a representative for the National Cattleman's Association found out about the amendment and took the opportunity to convince the Congressman to include a prohibition of haying and grazing. The House version up until now was silent about harvesting the CRP land but the Senate was considering allowing harvesting.

The original House version had no acres mentioned for the CRP. This was one of the amendments I was asked to check with Mr. Myers. De told me the Department would support a 20 million acre program. I relayed this to Susan Atkins, who is

Congressman Tom Coleman's staff person, and she and I developed an amendment which Congressman Coleman introduced to establish the CRP at a 20 million acre level. After the amendment passed, Congressman Edward Madigan added 5 million with a provision that the payments could be made with surplus commodities or payment in kind. The Senate had been considering a 30 million acre program, but at the last minute increased this to 40 to 45 million acres. The Senate version was adopted in conference, which was somewhat of a surprise because they usually just split the difference.

The original House version had no limit on what percentage of cropland acres in a county could be placed in the CRP. An amendment by Congressman Cooper Evans of Iowa added the 25 percent limit. There was quite a controversy about adding an amendment to make other than highly erodible land eligible for the CRP. In the long run, those in favor of keeping erosion control as the main emphasis won. The amendment was worded to allow, but not require, the Secretary to, "... where appropriate, accept contract offers that provide for the establishment of (1) shelterbelts and windbreaks, or (2) permanently vegetated stream borders, filter strips of permanent grass, forbs, shrubs, and trees that will reduce sedimentation substantially.

Now a short discussion on how the CRP fits with the other conservation provisions? Most of you by now are familiar with the three subparts of Title XII of the FSA - Conservation Reserve, Highly Erodible Land, and Wetland Conservation. You know that the Highly Erodible Land section is divided into two parts - Sodbuster and Conservation Compliance.

CRP can be considered the carrot and the other three provisions the stick. We made what I think is a serious error in not developing the rules for all these provisions together. We moved out so fast on the CRP that neither the farmer nor the Soil Conservation Service personnel have had time to develop conservation plans that will meet the Conservation Compliance requirements. Ideally, the conservation plans that are required by 1990 under the Conservation Compliance requirement should be developed, and the CRP and other cost share programs used as tools to help carry out these plans.

For this reason I have been against the bidding feature of the CRP from the start. I would have opted for pools with similar land to have been established as they were for the bidding pools and a rate that was acceptable to the Secretary be established for each pool. Then, as the farmer submitted a conservation plan that met the requirement of the Conservation Compliance section, they could be accepted as a CRP contract for any land they planned to convert to grass, trees or wildlife cover.

This follows the GPCP concept used by Harold Schoenhals which served not only to convert the land to grass but to convert the farmer to a conservation farmer.

Our job now is to try to catch up with the conservation planning required by the conservation compliance provision and hope to be able to incorporate the CRP contracts into those plans.

History of Cropland Set Aside Programs in the Great Plains

Earle J. Bedenbaugh[1]

When you examine historical accounts of agricultural policy the task can become monotonous, nonetheless, such reviews are often useful when trying to see into the future. When I look back over the past 60 years of farm programs, I come to the conclusion that, through these years, we have made short-term solutions to long-term problems. And, as this history unfolds, I think you probably will come to the same conclusion.

From the beginning of the 1930's, federal cropland programs have sought to adjust the production of certain commodities, in effect, to support the prices and incomes received by farmers. These programs over the years have included minimum conservation requirements on qualified acreage. Conservation was a secondary purpose even though conservation benefits at times have been quite significant. However, these programs were first and foremost aimed at price enhancement through supply control, and it was on that basis that their performance was usually evaluated.

For most of this century, the central problem in American agriculture has been one of overproduction, and we certainly have that problem today. Continual advancement from technology and cultural practices generally have kept production ahead of demand except during war time periods and a few short-term periods that we called the golden age of agriculture. These periods occurred between 1900 and 1914, and, more recently, we have seen evidence of this golden era of agriculture during the 1970's.

It was in the 1920's that the commodity supply problem first became critical enough bring about serious and widespread proposals for government intervention in the market place. A number of plans were proposed, but the legislation that was enacted, the Agricultural Marketing Act of 1929, soon proved unworkable. It attempted to bolster prices through purchases in storage loans to farm cooperatives; however, surpluses continued to glut the market and to depress prices. Short-term solutions to long-term problems.

The economic depression that would paralyze the rest of the nation in the 1930's struck first in agriculture when sharp price decreases and drops in exports left overextended farmers with heavy debts, reduced acreages, and low income. This certainly sounds like today, doesn't it?

By 1933 the crisis had deepened, and farmers were increasingly desperate. Export markets had virtually dried-up, the already low farm prices tumbled to levels not seen before in this century, and foreclosures and forced auctions had swept through the farmbelt. Even the Farm Bureau warned of revolution in the countryside if something was not done to help American farmers. The government responded to this emergency with the Agricultural Adjustment Act (AAA) of 1933 which for the first time authorized production controls as a primary means of raising farm prices and farm income. The AAA provided a number of tools to deal with the farm crisis, including acreage control, margin agreements, direct payments to farmers, nonrecourse law, and authority to tax and license processes. They charged a new agency, the Agricultural Adjustment Administration, with the task of developing and operating specific commodity programs with the assistance of producer committees.

Wheat, cotton, corn, hogs, rice, tobacco, and milk were covered by the original legislation, and more commodities were added later. It can be safely said that the Secretary of Agriculture received more discretionary authority under the AAA to make and change farm policy than in any subsequent farm bill. The Act was a voluntary production control contract in which individual farmers agreed to reduce their acreage in return for direct payments financed by a tax on processes. These were voluntary programs. As an additional emergency measure, cotton and tobacco farmers plowed up portions of their growing crops in 1933 in return for rental payments. The first programs for these crops were voluntary; however, at the urging of producers and the producer committees that were in place at that time, cotton and tobacco became compulsory programs. Heavy taxes were levied on noncompliers using acreage controls approved in a referendum of producers. Again short-term solutions to long-term problems.

The Great Plains economic depression was magnified during the 1930's by devastating droughts and dust storms. The old farm-out-and-move-on philosophy that had lingered throughout the region bore bitter fruits in the dustbowl days of the plains. According to an old AAA pamphlet, Great Plains farmers were among the longest and strongest supporters of the AAA in the

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early days. In 1934, 88% of North Dakota farmers and 80% of South Dakota farmers participated in the Program, leading all other states. Participation was also high in Nebraska, Texas, and Oklahoma. With strong support from farmers and farm organizations, AAA programs did work to significantly reduce acreage, although drought also figured considerably in the production decreases.

Prices for commodities rose markedly after passage of the AAA. Farm incomes rose 50% from 1932 to 1935, primarily due to direct payment from the government. However, in 1936 the Supreme Court invalidated the production control contracts and processing tax features of the law, and the adjustment program came to an abrupt halt. Fearing the prospect for renewed overplanting and depressed prices, USDA and farm leaders urged Congress to swiftly pass new legislation before spring planting. Enacted one month after the Supreme Court decision, and I wish we could get legislative positions to come into place as quickly now, the Soil Conservation and Domestic Allotment Act made soil conservation the rationale for acreage cuts. The Soil Conservation Service (SCS) was founded in 1936, and helped start a conservation effort that we have been going through for the last 50 years.

Farmers received payments for voluntarily shifting from crops to soil conserving grasses and legumes on their lands. They were also paid for adopting soil building practices. Unfortunately, severe drought temporarily masked the programs inadequacy for controlling production, but when surpluses grew and prices toppled in 1937 there was no doubt that more action was needed to divert renewed production. Again we see short-term solutions for long-term problems.

In 1938 Congress passed a second Agricultural Adjustment Act which, with many amendments and modifications over the years, has remained on the books as our Nation's fundamental farm support law until this date. It retained the voluntary allotment conservation payment provision of the 1936 law, but added mandatory controls in the form of marketing quotas for wheat, corn, cotton, tobacco, and rice. When supplies were expected to exceed certain levels, marketing quotas had to be proclaimed; however, the quota in practice did not limit the quantity farmers could produce or market, but rather the acreage needed to produce those quotas. If farmers approved the quotas by a two-thirds majority, allotments become mandatory and farmers were limited to planting a specific percentage of their historical acreage. Noncompliers paid a very heavy penalty.

This system of limiting acreage rather than quantity was more acceptable to farmers since it allowed them to raise as much as they could on their reduced acreage. However, while the quotas and allotments that were put into effect under law generally succeeded in reducing acreage, production did not fall proportionately. Farmers participated heavily, but yields rose through more intensive farming practices and, in the case of corn, the use of hybrid seed. Thus, as a means of supply control, it allowed considerable slippage.

World War II brought a temporary end to mandatory controls as farmers were urged to increase production for the war effort. The large stocks that had accumulated in graineries become a military reserve of crucial importance to the United States and our allies. To ensure plentiful production, the government offered guarantees of high fixed price support in contrast to the lower adjustable loan rates of the 1930's. New commodities were continually added to the support list for the war effort. By the end of World War II, more than 100 commodities were being supported. The basic program structure set by the 1938 Act remained in place, but was adapted to promote production for war crops. For instance, farmers in states with minimum acreage requirements for soil conserving crops were notified that soybeans would be classified as an erosion resisting crop for payment purposes.

High demand during the Korean war offered a temporary reprieve from problems of surpluses; however, by 1954 mounting surpluses led to the legal requirements for marketing quotas once again.

The Eisenhower Administration philosophically opposed mandatory controls, preferring a more market-oriented policy toward flexible and lower price supports. These proposals ran aground in Congress, and compromise legislation that passed in 1954 proved ineffective primarily because of rapidly increasing productivity. Productivity grew at a faster pace during the 1950's than in any previous decade of the century. Encouraged by high war time prices and price guarantees, farmers were making heavier use of fertilizers and pesticides, and were rapidly adopting a host of new high yielding crop varieties, better breeds of livestock, and labor saving machinery. However, the control programs, themselves, had their usual effects on intensifying production on permitted acres.

Another reason the acreage program did not work well in the 1950's was that they were no longer applied as strictly as they had been in the past. For example, the use of land removed from production of allotment quota crops had changed substantially. In the late 1930's this land had to be planted in soil- conserving crops, generally grasses and legumes. But the definition of soil-conserving changed during the war years so, when the controls were imposed in the 1950's, reduced acreage could be planted with almost anything except for marketing quota crops. This situation became known in the USDA as "shifting of surpluses." Diverted acres were planted in crops that soon themselves were over- produced. Much of the land taken out of corn, for example, went into soybeans, rye, flax seed, and hay. Again short-term solutions to long-term problems.

In 1956 the stage was set for a new acreage control program that sought to retrieve more of the land than could be reached under the allotment system. It was called the Soil Bank. The Soil Bank became the largest land retirement program enacted since the 1930's. Farmers at that time were often accused of being wards of the government. As one witticism went, "A farmer put his land in the soil bank, his rear end on the river bank, and his money in the national bank." We in agriculture have obviously lived with that image ever since.

The Soil Bank had two parts. Acreage reserve was a short-term acreage reduction for wheat, corn, cotton, rice, tobacco, and

peanuts. Farmers received payments for converting land to conserving use. The long-term Conservation Reserve was open to all farmers, and retired land under three to ten-year contracts in return for cash rentals. Conservation cost-sharing payments were made for maintaining permanent cover on these idle acres. Soil Bank had ambitious goals but neither of the two reserves were very successful in slowing production. In its peak year the acreage reserve idled 21.4 million acres, but it was so costly that Congress ended the program in 1958. Another short-term solution of a very long-range problem.

By 1960 the Soil Bank Conservation Reserve signed up 27.7 million acres or about 6% of the total U.S. cropland. This included 15 million acres formerly planted to wheat and feed grains. To curb intensive farming on land outside the Soil Bank, the government encouraged the removal of whole farms; thus 70% of the crop land in conservation reserve was taken out in whole farm units. The program had no erodibility criteria for entry, but it nevertheless retired largely marginal land. Consequently, it had little appreciable effect on production and surpluses. Its conservation benefits were substantial in areas where participation was the highest, however.

The Soil Bank returned grasses to vast areas of the Great Plains that had been planted in grain during the war years. In the Southeast 2 million acres of trees were planted, thereby encouraging a growing forest industry in that region. More than 300,000 ac. were devoted to wildlife habitat. However, wide spread opposition to the program by local businessmen and farm suppliers led to the end of the Soil Bank days. The Administration was unable to renew that Soil Bank in 1960, although the last land under contract did not leave the program until the early 1970's.

By 1960 the stock levels of corn and wheat set record highs and prices of these crops were at the lowest levels since the 1940's. The Kennedy Administration was, nonetheless, convinced that mandatory controls could work to manage supply if the mechanism was switched from acreage control to true quotas on the amounts that could be marketed. Under the proposed plan, farmers of any crop would be able to vote on whether to implement marketing quotas that offered a high price support or to return to acreage cuts. Minimal national acreage allotments would be abolished. Congress rejected this extensive system of mandatory controls, but it did approve a referendum on the plan for wheat producers in 1963. However, wheat producers decisively turned down the proposal after a heated campaign.

Legislation that followed the wheat producers referendum set the pattern for future programs in that voluntary rather than mandatory controls were used to adjust production for most crops. Mandatory controls on corn had ended in 1950, preceding the rejection of quotas by wheat producers in 1963. Programs for these crop years emphasized voluntary acreage reduction as a contingent for price support. However, farmers could receive payments in cash or in kind if they diverted additional acres to conserving uses. These voluntary programs successfully retired large acreages through the decade but at considerable cost. Optional paid diversions and supplemental price support programs pushed payments to farmers up from 1.7 billion dollars in 1960 to 3.7 billion dollars in 1970. On the other hand, surpluses were basically under control despite yield increases, mostly as a result of rising exports during the 1960's which helped to absorb these production increases.

A major change in world markets in the early 1970's, caused by unprecedented Soviet grain purchases and world crop shortages, resulted in sharp increases in U.S. exports. Market prices moved well ahead of support levels and government stocks were liquidated.

As concern shifted from crop surpluses to world food shortages, Secretary Butz emphasized increasing rather than decreasing production, and freed farmers from planting restrictions for the first time in 30 years. Most set aside lands in the early 1970's gave way to none at all for wheat and seed grains from 1974 to 1977, cotton from 1973 to 1981, and for rice from 1976 to 1982. Spurred by higher prices, farmers added 20 million acres to cropland before the decade had ended. Unfortunately, the fence-row-to-fence-row planting spree included plowing millions of acres of fragile rangeland and other highly erodible land. Many wetland areas were drained and converted to marginal cropland.

The impact of commodity programs on resource conservation became a stronger issue in the following years. Policymakers became concerned that millions of cropland acres were eroding above the soil loss tolerance. In the 1980's, as we know, the economic climate changed dramatically. A number of factors, including worldwide recession, a strong dollar, rigid price supports, and record foreign and domestic production, combined to sharply reduce both U.S. export levels and crop prices. Secretary Block tried a small acreage diversion program in 1982, but it was not effective because of good weather and high yields. By 1983 government-held stocks, grain, and cotton were approaching and surpassing records set in the late 1950's. Again, a series of decisions that represented short-time solutions to long-term problems.

In that year the Administration launched a Payment-In-Kind (PIK) Program, the largest acreage diversion program in history. Under PIK farmers could choose to idle from 10-30% of their basis on top of the unpaid diversion in return for deliveries of the same commodities. Participation was extremely high, and an unprecedented 78 million acres were diverted to conserving uses.

Together with a drought, the Program reduced total production of PIK commodities by about 35%. Surplus stocks of feed grains, rice, and cotton fell substantially. PIK also resulted in a reduction of average erosion by 1.4 tons per acre for the lands in the Program, according to a recent study. Since 1984, however, surpluses have continued to grow despite large acreage reductions and paid diversions. About 43 million acres were idle in 1986, and the Program will idle approximately 54 million acres in 1987. If we add this figure to the nearly 23 million acres enrolled in conservation reserve programs, the total is close to that idled during the 1983 PIK program. Nonetheless, commodity prices still go down, exports go down, and again a short-term solution to a long-term problem.

The Food Security Act (FSA) of 1985 added some important provisions to reduce adverse impact of commodity program

incentives on use of marginal land. These provisions known as Sod Buster, Swamp Buster, and Conservation Compliance, deny federal farm program benefits to farmers who produce crops on highly erodible lands or who drain wetlands for crop production without an approved conservation plan. Conservation has been used as rationale for production adjustment in past years, but this is the first time eligibility for farm program benefits have been made contingent upon proper soil stewardship.

The new Conservation Reserve Program (CRP) of the FSA is intended to bring more consistency to commodities and conservation program objectives. Unlike the old Soil Bank Program, the CRP specifically targets the idling of highly erodible land. Given our continued problem of surpluses, it makes no sense to encourage unneeded production on land where erosion is already a problem. However, CRP is not viewed as primarily a reduction adjustment program with secondary conservation benefits. It is a conservation program that will have a desired impact on reducing surplus production as more land is enrolled. Unfortunately, as we view 50 years of experience with acreage control, we can see that success in limiting overall production by this means has been limited at best, primarily because farmers have always farmed permitted acres more intensively when a controlled program is in place. But, mandatory or voluntary, these programs still serve as a mechanism to slow increases in crop production.

Acreage control has been seen as a necessary part of price support programs by every administration that has had to face the problem of overproduction. The Reagan Administration is no exception. The solution we have proposed involves gradual phase-outs of both price and income supports and, along with that, a need for acreage control programs. So far, this has been rejected by Congress. We believe there is considerable recognition of the need for a serious forum of our price support and production adjustment machinery. Until this is achieved, however, we will continue, as our predecessors did, to use the tools at our disposal.

It is estimated that this year we will see again dramatic changes in farm legislation and amendments to the 1985 Food Security Act. I think at some point in time we are going to have to take a basic sound philosophy concerning agricultural legislation, put it into effect, and see it to its ultimate end. It is very difficult to see things to an end sometimes.

Climate and Weather of the Great Plains

Gene C. Wilken[1]

Abstract.--Great ranges of temperature and precipitation are products of atmospheric controls, especially continentality and air masses. Average conditions establish the general climate, but extreme events also are "normal." Strategies to deal with such uncertainties should incorporate data on average and extreme conditions, relationships between climate, crops, and economic activities, and experiences from analogous regions.

Perhaps the two most distinctive features of Great Plains climate and weather are range and variability. These two characteristics introduce high levels of risk and uncertainty to many economic and social activities in the region. Since the weather itself cannot be controlled, decisionmakers and planners must develop strategies based on an understanding of the climate, and flexible responses to its uncertainties.[2]

Two aspects are important; (1) the average conditions, including normal variations, that set the general context for biological and economic activities, and (2) the likelihood that the actual weather at any particular time or place will deviate from the norm. Both the average conditions and the deviations are important for those who make decisions and plan. This paper will briefly consider some basic features of Great Plains climate, especially those that contribute to its range and variability, types of information that are readily available, and strategies for coping with Great Plains weather and climate.

Characteristics of Great Plains Climate

Winters in the northern Great Plains are the coldest in the contiguous 48 states. Often, the plains are cold all over (fig. 1)! In January parts of Texas and Oklahoma can be as cold as Michigan and Ohio, far to the north (Rosenberg 1987). In the summer the Great Plains can be as hot as parts of the tropics (fig. 2). Fall and spring, during which the region makes the shift from northern cold to tropical hot, are transition periods of great change in temperature and precipitation.

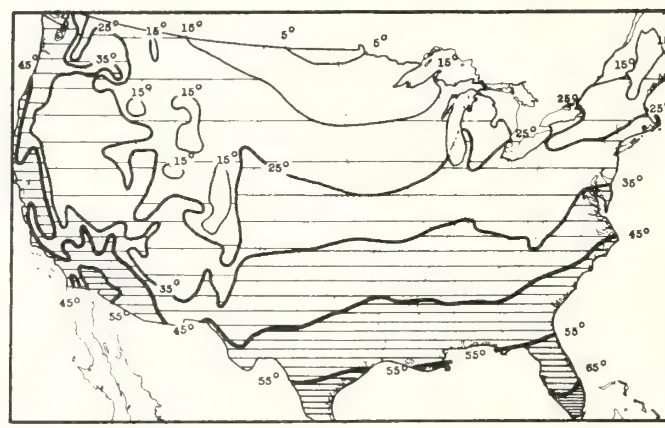

Figure 1.--Normal winter temperature (Visher 1954:24).

To understand these ranges and variations we must look at the physical region and its major atmospheric controls. Much of the climate of the Great Plains is explained by three of these controls: continentally, air masses, and mountain barriers.

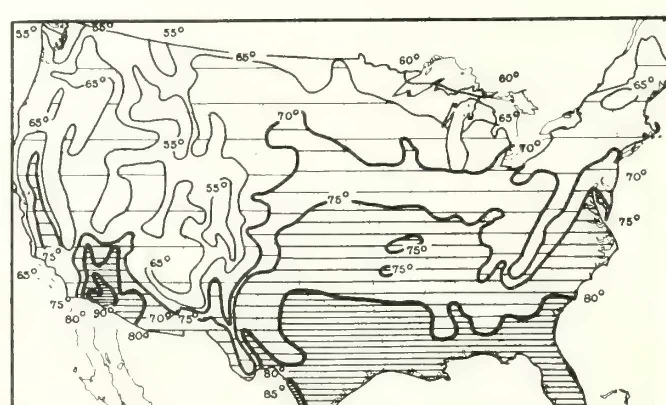

Figure 2.--Normal summer temperature (Visher 1954:24).

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[2]As used here, weather is what is experienced at any particular time: hot or cold, wet or dry, windy or calm. Climate is a statistical description of what should occur on the average. Seldom if ever does a completely average season or year occur since most of the time the temperature, precipitation and other weather elements are either above or below average.

Continentally refers to the great temperature ranges associated with major land masses. Large water bodies such as seas or oceans heat and cool slowly and maintain relatively uniform temperatures throughout the year. The resulting moderate or maritime temperature regime may be transferred to adjacent land areas by wind systems. On the other hand, land surfaces heat and cool quickly both diurnally and annually. The Great Plains, located deep within the North American land mass and far from the moderating influence of major water bodies, have a continental temperature regime of great annual range.

Air masses, the second control, are large bodies of lower atmosphere, on the order of hundreds of square miles in size, that have fairly uniform characteristics of temperature and humidity that they take from the surfaces over which they form. The temperatures from warm southern or cold northern land masses, or from moderate ocean surfaces are imparted to the air masses above them by radiation and turbulent mixing. In addition, more water generally evaporates from ocean surfaces than from land areas. Combinations of these temperature and moisture conditions identify four major air mass types:

Type	Symbol	Characteristics
Continental tropical	(cT)	warm-dry
Continental polar	(cP)	cold-dry
Marine tropical	(mT)	warm-wet
Marine polar	(mP)	cold-relatively wet

Once air masses have taken on the characteristics of the underlying surfaces they may move out of their source areas and transfer these characteristics to other regions. Common source areas for air masses that invade the Great Plains are:

Air mass	Source area
cT	U.S. southwest
cP	Canada and the northern states
mt	Gulf of Mexico
mP	Northern Pacific/Gulf of Alaska

Air mass movements are also influenced by mountain barriers. The mountain ranges of the western United States trend mostly north-south, or perpendicular to the westerly winds that prevail at these latitudes. The mountains partially block invasions of mp air masses from the west and contribute to the generally semi-arid conditions, especially in the western Great Plains (fig. 3).

On the other hand, the region is open to invasions of mT (Gulf), cP (Canadian) and cT (Southwest) air masses that originate to the north and south. The result is that the Great Plains are a battle ground of air masses: Bitterly cold air out of the north in the winter; warm wet air from the Gulf of Mexico in the spring (which brings much of the annual precipitation), and occasionally hot dry air from the Southwest during summer.

Unsettled weather and precipitation often occur along the plane of contact, or front, between air masses of different characteristics. The Great Plains are also the windiest part of the United States as a result of the frequent air mass exchanges and flat nature of the region.

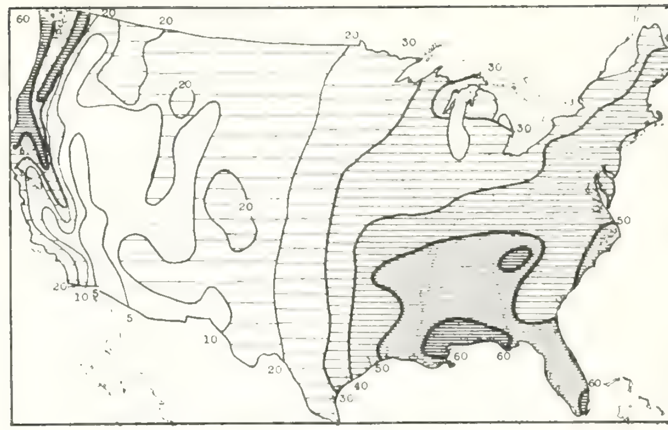

Figure 3. Normal annual precipitation, in inches (Visher 1954:197).

Superimposed on the average march of seasons are longer-term variations: clusters of wet or dry, or hot or cold years that may persist for a decade. But these should not be considered aberrations since "normal" conditions are only statistical averages of actual weather that usually range above and below the mean. Short- and long-term deviations from the mean are also normal parts of Great Plains weather.[3]

In extreme cases variability goes beyond the normal range and constitutes a climatic hazard, the most familiar of which is drought but can also be exceptionally hot or cold temperatures, high winds, early or late frosts, violent thunderstorms and hail, and tornadoes. One hazard can be threatening enough; if two or more hazards occur together, such as drought and high winds, the results can be catastrophic. But even these extreme events, or hazards, are part of the Great Plains environment, to be expected from time to time (Warrick 1980).

Information

The constantly changing climate poses a continuing challenge to life on the Great Plains. Since little can be done about the weather itself, the solutions are primarily managerial; i.e., knowing about average conditions, and probabilities of extreme events, and being flexible enough to work with, not against, these difficult conditions.

Data on the climate, especially temperature and precipitation, but also such elements as wind, evaporation, cloudiness, and solar radiation, are abundant. Medium- to long-term records exist for dozens of stations in the Great Plains. Averages have been calculated and extremes recorded, in some cases for more than 50 years. General climatic features of most locations are

[3]Evidence from tree ring analyses and historical materials suggest that parts of the Great Plains have experienced droughts in the past more severe than any that have occurred in recent times. Such long and severe events would impact heavily on the modern economy of the region.

well known, as are the probabilities of specific events occurring at any particular time. Thus, the statistical probability of frost at any particular date and length of frost-free season are known for most of the major weather stations. In addition, published materials contain such things as number of clear days during the year, zones and speeds of high winds, number of hailstorms for a particular area, sequences of wet or dry days, and drought extent and severity (Benci and McKee 1977; Berry 1968).

Besides climatic data, there are studies of interactions or relationships between biological and social activities and weather elements. The most familiar of these are crop-climate relationships; e.g., heat and water requirements of common crops. Correlations in the public utility area, such as heating fuel consumption in relation to degree days, and water consumption at various levels of temperature and precipitation also are common. In addition, studies of cattle weight gain, public transportation use, shopping behavior, health, and even crime in relation to various weather elements are available.

Combining data on climate averages, normal ranges, and probabilities of extreme events with the various biological and social responses can reduce the uncertainty and risk of dealing with Great Plains weather. With available data, contingency plans can be developed for almost any condition, even in the climatically variable Great Plains.

Strategies

Dealing with the Great Plains environment requires a high degree of flexibility. In farm and ranch operations flexibility is achieved through alternative crops and timing of field operations, and actual climate-modifying techniques such as irrigation, windbreaks, and shading. Flexibility is also provided by equipment and staffing levels. For example, a large proportion of capital equipment that distinguishes United States agricultural enterprises from those in other parts of the world allows Great Plains farmers to take advantage of short spells of favorable weather to plant and harvest.

Another basic strategy for dealing with the environment involves anticipation or prediction. To be useful, reliable estimates on what will occur should be available far enough in advance so that defensive measures can be taken. Because of the magnitude of forces involved and the enormous number of variables, the task is extraordinarily difficult. Nevertheless, satellites and computers are providing more and better short-term and intermediate forecasts and eventually long-range forecasts of sufficient accuracy to use in planning may be possible.

Finally, identifying strategies from other regions would be useful. Similar environments, or agroclimatic analogues, occur elsewhere in the world. For example, the Ukraine of the Soviet Union is reasonably close climatically to the Great Plains (Granovskaya 1968; Nuttonson 1965), and there are other areas in Africa, Asia, and South America that are comparable. However, different histories and customs in these analogous regions have produced different management techniques. It would be of considerable interest to know how people and institutions in other parts of the world respond to the normal and unusual conditions that occur in these similar environments.

Could the methods used in other regions really be useful here? Although social and technical differences are often great, the analogous regions share the great ranges and variations of temperature and precipitation, and high levels of risk and uncertainty found in the Great Plains. Comparable challenges call forth comparable responses. The experience of others might well offer new alternatives for planning and management in this difficult environment.

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Historical Development of Native Vegetation on the Great Plains

James Stubbendieck[1]

Abstract.--Original vegetation of the Great Plains was primarily grassland. Over 20 types of natural vegetation are placed into six categories and the dominant species are listed. The environmental factors and historical events influencing evolution of grasses, grasslands, and herbivores are discussed.

One of the largest real estate purchases in the world was made in 1803 when the Government of the United States, under the direction of President Thomas Jefferson, purchased over 500 million acres from France for $15 million. This purchase included most of the Great Plains depicted in figure 1. Little was known about the resources, including the vegetation, at the time of the purchase. Only a few trappers and explorers had extensively traveled in the area. Unfortunately, some early organized explorations coincided with periods of drought. Much of the Great Plains was condemned as the "Great American Desert." This title presented a particularly stubborn obstacle to settlement (Emmons 1971), and may have only meant that the area was deserted, especially by man (Murray 1897). The area was not a desert. It was covered with vegetation, primarily prairie vegetation (von Humboldt 1896).

Vegetation is a term that is collectively used to describe the plant life of an area. The vegetation of the Great Plains has been variously described as prairie, grassland, and rangeland. Prairie has been defined simply as an extensive tract of level or rolling land that was originally grass-covered and treeless (Range Term Glossary Committee 1974). This land is not necessarily currently covered with prairie vegetation or with vegetation originating in North America. Others have more complex and emotional views of prairies (Rose 1975). Prairie vegetation is predominantly grasses, but forbs, grasslike plants, and woody plants are common (Weaver 1954). Prairies must evolve. They are not planted. On the other hand, the term grassland is used to describe any area on which grasses dominate. These grasses are not necessarily native to those areas. One phase of the Conservation Reserve Program (CRP) is to establish grasslands, not prairies. Another term requiring definition is rangeland. It is dominated by vegetation useful for grazing or browsing (Range Term Glossary Committee 1974). Management is routinely through grazing rather than by renovation and/or cultural treatment.

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One purpose of this paper is to briefly describe the types of natural vegetation found on the Great Plains and the factors affecting vegetation. Evolution of grasses, grasslands, and herbivores will be discussed.

Vegetation of the Great Plains

The grassland biome of the Great Plains is the largest vegetational unit in North America (Gould and Shaw 1983). Decreasing precipitation across the Great Plains from east to west is accompanied by changes in productivity and species composition (Weaver 1954). As a result, three major regions have been distinguished (Oosting 1956). The eastern part, where the precipitation is the highest, is generally called the true prairie or tall grassland. The dominant grasses are usually over 4 ft. in height. The short grassland occurs in the driest regions, and dominant grasses are usually less than 2 ft. The mixed grassland is in the center where grasses are of intermediate and mixed heights.

Diversity of the natural plant communities of the Great Plains is illustrated by the occurrence of over 20 types of natural vegetation (Kuchler 1964). These can be grouped into six broad categories (fig. 2).

Black Hills Forest

Black Hills Pine Forest *(Pinus)*[2] is located in South Dakota and Wyoming. The dominant is tree ponderosa pine *(Pinus ponderosa)*[3]. Grasses such as western wheatgrass *(Agropyron smithii)*, bluebunch wheatgrass *(Agropyron spicatum)*, blue grama *(Bouteloua gracilis)*, and needleandthread *(Stipa comata)*

[2]*Natural vegetation types generally follow Kuchler (1964), but they have been modified and updated to reflect current knowledge and taxonomy.*

[3]*Nomenclature follows Stubbendieck et al. (1986) or the Great Plains Flora Association (1986).*

are common in open areas. Threadleaf sedge *(Carex filifolia)* and other carices add to the grazing resource.

The Eastern Ponderosa Forest *(Pinus)* is located in Montana and is also dominated by ponderosa pine. Western wheatgrass, blue grama, and needleandthread are common in the open forest.

The Northern Floodplain Forest (Populus-Salix-Ulmus) borders the rivers and streams from Oklahoma northward. Only a few understory plants produce adequate quantities of forage for grazing.

Hardwood Savanna

A hardwood savanna occurs along the southeastern edge of the Great Plains. Much of it is not completely forested but is a mosaic of Oak-Hickory Forest *(Quercus-Carya)* and Bluestem Prairie *(Andropogon-Panicum-Sorghastrum)*. Oak-Hickory-Pine Forest *(Quercus-Carya-Pinus)* and Cross Timbers *(Quercus-Schizachyrium)* are represented in the southern portion of the Grassland Forest. Few forage producing plants grow in the Oak-Hickory-Pine Forest. Trees are scattered or in extensive groves in the Cross Timbers. Little bluestem *(Schizachyrium scoparium)* is a dominant. Other important forage species are big bluestem (*Andropogon gerardii* var. *gerardii*), sideoats grama *(Bouteloua curtipendula)*, hairy grama *(Bouteloua hirsuta)*, Canada wildrye *(Elymus canadensis)*, purple lovegrass *(Eragrostis spectabilis)*, sand lovegrass *(Eragrostis trichodes)*, switchgrass *(Panicum virgatum)*, indiangrass *(Sorghastrum nutans)*, tall dropseed *(Sporobolus asper)*, and Texas wintergrass *(Stipa leucotricha)*.

Figure 1.--Location of the Great Plains.

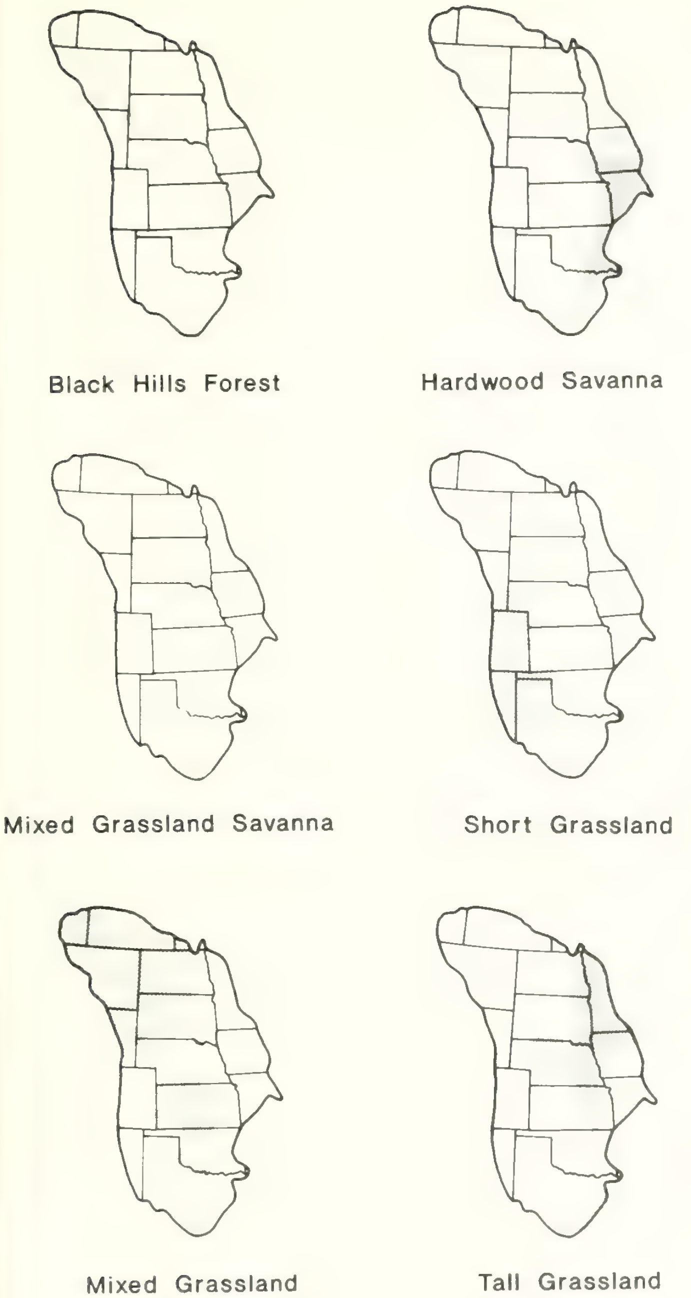

Figure 2.--Types of original vegetation on the Great Plains.

Mixed Grassland Savanna

Mixed Grassland Savanna is found primarily in west-central Texas. It is comprised of Mesquite-Oak Savanna *(Prosopis-Quercus-Schizachyrium)*, Juniper-Oak Savanna *(Juniperus-Quercus-Schizachyrium)*, Mesquite-Buffalograss *(Prosopis-Buchloe)*, and Mesquite Savanna *(Prosopis-Hilaria)*. These types of vegetation have trees in varing densities with understories of grasses. The most abundant and important grasses are little bluestem, buffalograss *(Buchloe dactyloides)*, threeawns (*Aristida* spp.), sideoats grama, hairy grama, silver bluestem *(Bothriochloa saccharoides)*, green sprangletop *(Leptochloa dubia)*, vinemesquite *(Panicum obtusum)*, curly mesquite *(Hilaria belangeri)*, and tobosa *(Hilaria mutica)*.

Short Grassland

The Short Grassland is located on the high plains which extend from the Texas panhandle to southeastern Wyoming. This area lies in the rain shadow of the Rocky Mountains and receives the least amount of precipitation. Over 90% of the area is Grama-Buffalograss *(Bouteloua-Buchloe)*. Dominants are blue grama and buffalograss. Many of the other components are different in the north than in the south. Cool-season species, such as western wheatgrass, are more abundant in the north, while the warm-season grasses sideoats grama and ring muhly *(Muhlenbergia torreyi)* are more abundant in the south. Other important species include red threeawn *(Aristida purpurea)*, hairy grama, western wheatgrass, scarlet gaura *(Gaura coccinea)*, curlycup gumweed *(Grindelia squarrosa)*, ironplant *(Haplopappus spinulosus)*, prickly pears (*Opuntia* spp.), woolly plantain *(Plantago patagonica)*, slimflower scurfpea *(Psoralea tenuiflora)*, upright prairieconeflower *(Ratibida columnaris)*, senecios (*Senecio* spp.), scarlet globemallow *(Sphaeralcea coccinea)*, sand dropseed *(Sporobolus cryptandrus)*, and small soapweed *(Yucca glauca)*.

Mixed Grassland

Mixed Grassland occupies the largest area in the Great Plains. It is located in the northwest and in an area in the south-central Great Plains separated by the Nebraska sandhills. As its name implies, the Mixed Grassland contains short, mid, and tall grasses. But, it also includes many species of forbs. The vegetation in the south-central area is primarily Bluestem-Grama Prairie *(Schizachyrium-Bouteloua)*. Dominants are little bluestem, sideoats grama, and blue grama. Other important components are western wheatgrass, western ragweed *(Ambrosia psilostachya)*, leadplant *(Amorpha canescens)*, big bluestem, buffalograss, Fremont clematis *(Clematis fremontii)*, slender dalea *(Dalea enneandra)*, black samson *(Echinacea angustifolia)*, western wallflower *(Erysimum asperum)*, dotted gayfeather *(Liatris punctata)*, evening primrose *(Oenothera serrulata)*, switchgrass, slimflower scurfpea, indiangrass, and tall dropseed. The majority of this area has been placed into cultivation, but relatively large tracts remain in native vegetation.

A vegetation type occupying a much smaller area is the Sandsage-Bluestem Prairie *(Artemisia-Schizachyrium)*. It is scattered along the western edge of the Mixed Grassland. It contains many species of grasses and a strong element of dwarf shrubs. Dominant plants are little bluestem, sand sagebrush *(Artemisia filifolia)*, hairy grama and sand bluestem (*Andropogon gerardii* var. *paucipilus*). Other components include blue

grama, buffalograss, prairie sandreed *(Calamovilfa longifolia)*, sand lovegrass, prairie sunflower *(Helianthus petiolaris)*, foxtail barley *(Hordium jubatum)*, switchgrass, blowoutgrass *(Redfieldia flexuosa)*, sand dropseed, needleandthread, and small soapweed.

Grama-Needlegrass-Wheatgrass *(Bouteloua-Stipa-Agropyron)* is located immediately east of the Rocky Mountains in Alberta, Montana, and Wyoming. Dominants are blue grama, needleandthread, and western wheatgrass. Other components include bluebunch wheatgrass, fringed sagewort *(Artemisia frigida)*, threadleaf sedge, hairy goldaster *(Chrysopsis villosa)*, prairie junegrass *(Koeleria pyramidata)*, dotted gayfeather, plains muhly *(Muhlenbergia cuspidata)*, sandberg bluegrass *(Poa sandbergii)*, little bluestem, sand dropseed, green needlegrass *(Stipa viridula)*, and broom snakeweed *(Xanthocephalum sarothrae)*.

Wheatgrass-Needlegrass *(Agropyron-Stipa)* is directly east of the Grama-Needlegrass-Wheatgrass vegetation type. Dominants are western wheatgrass, needleandthread, and green needlegrass. Other important components are slender wheatgrass *(Agropyron trachycaulum)*, pussytoes (*Antennaria* spp.), fringed sagewort, sedges, prairie junegrass, indian ricegrass *(Oryzopsis hymenoides)*, penstemons (*Penstemon* spp.), little bluestem, cudweed sagewort *(Artemisia ludoviciana)*, heath aster *(Aster ericoides)*, black samson, dotted gayfeather, silverleaf scurfpea *(Psoralea argophylla)*, goldenrods (*Solidago* spp.), and porcupinegrass *(Stipa spartea)*.

The Wheatgrass-Bluestem-Needlegrass *(Agropyron-Andropogon-Stipa)* vegetation type is located in a narrow band along the eastern edge of the Mixed Grassland. The dominants are western wheatgrass, big bluestem, and porcupinegrass. Other important components are slender wheatgrass, little bluestem, fringed sagewort, heath aster *(Aster ericoides)*, cudweed sagewort, sideoats grama, blue grama, black samson, prairie junegrass, dotted gayfeather, silverleaf scurfpea, wild rose *(Rosa arkansana)*, prairie goldenrod *(Solidago missouriensis)*, needleandthread, and green needlegrass.

Tall Grassland

Tall Grassland includes three important vegetation types. The Bluestem Prairie *(Andropogon-Panicum-Sorghastrum)* is sometimes called the True Prairie. The dominants are big bluestem, little bluestem, switchgrass, and indiangrass. Other components are leadplant, pussytoes, heath aster, blue aster *(Aster laevis)*, wild indigos (*Baptisia* spp.), sideoats grama, daisy fleabane *(Erigeron strigosus)*, small bedstraw *(Galium trifidum)*, sunflowers (*Helianthus* spp.), prairie junegrass, gayfeathers (*Liatris* spp.), scurfpeas (*Psoralea* spp.), prairie coneflowers (*Ratibida* spp.), wild rose, compassplant *(Silphium laciniatum)*, goldenrods, prairie dropseed *(Sporobolus heterolepis)*, and porcupinegrass. The Bluestem Prairie is located from northwest Minnesota into northeast Oklahoma. Except for the Flint Hills region in Kansas and adjacent Osage Hills in Oklahoma, most is under cultivation.

Nebraska Sandhills Prairie *(Andropogon-Calamovilfa)* occurs in north-central Nebraska. Due to the soil-water relationships, this area supports tall grasses even though receiving precipitation that would normally support only mid grasses. Dominants are sand bluestem, prairie sandreed, switchgrass, little bluestem, and needleandthread. Other important species are big bluestem, sand lovegrass, indian ricegrass, sand dropseed, daleas, and scurfpeas. Most of this area remains in native vegetation. The development of center-pivot irrigation made it possible to grow corn and other crops in the Sandhills. Many acres of highly erodible soils were plowed. Lowered grain prices and increased energy charges caused the abandonment of many fields (Oldfather 1984). Blackland Prairie *(Schizachyrium-Stipa)* is located along the southeastern edge of the Great Plains. The dominants are little bluestem and Texas wintergrass. Other important species are big bluestem, red threeawn, sideoats grama, switchgrass, indiangrass, tall dropseed, silver bluestem, and buffalograss.

Factors Influencing Vegetation

Composition of the vegetation is due to the combination, in varying patterns, of the separate individual distributions of all plants. But, vegetation is far more than a mere grouping of individual plants. It is the result of interactions of numerous factors. Distribution of individual species, as well as the location of each individual plant, is determined by a complex set of environmental factors (French 1979). The most important climatic factor is precipitation. Water is the primary limiting factor on grasslands. Precipitation, therefore, directly controls the type of vegetation a site will support. The true prairie receives enough total precipitation to support forests; however, uneven seasonal distributions tend to preclude forest establishment (Gleason and Cronquist 1964). Fire, the pyric factor, has also been historically responsible for helping to maintain the prairie vegetation, particularly near its eastern boundaries where precipitation is less limiting. Native grasses and forbs are adapted to fire, while woody vegetation is not (Wright and Bailey 1982).

Physiographic factors, such as topography, locally influence vegetation. Edaphic factors may control which species occur in an area. Fertility of the soil is directly related to the productive capacity of the area. Some important species are seldom found on coarse textured soils, such as sands. Others may only be found on coarse sands. Soil texture and structure are also related to water infiltration and water holding capacity. Biotic factors influence the distribution of plants. A broad spectrum of living organisms are found in grasslands. The final consideration is the anthropic factor. Man's activities are responsible for the current conditions of grasslands and prairies.

Complex combinations of these factors influence rate of succession by influencing chance, selection, and modification (Gleason and Cronquist 1964). The final result is climax vegeta-

tion--that which is in a state of equilibrium with its climate and soils (Billings 1978, Daubenmire 1968). The factors of the environment are dynamic and cause the vegetation to be dynamic.

Origin of Grasslands

Current distributions of plants cannot be totally explained by the current factors of the environment. Several questions need to be answered. How have plants attained the range that they now occupy? Have they always been there? Did they evolve all over their present range? In order to obtain the answers to these questions, paleoecological events influencing plant distribution must be explored.

Paleoecological Events

The Rocky Mountains first arose about 135 million years ago during the Mesizoic Era and then eroded, forming a plain to where the Mississippi River is now located. Flowering plants became successful about 110 million years ago, and the first grasses evolved about 65 million years ago (Raven and Axelford 1974). A temperate forest occupied the Great Plains during the Eocene (about 60 million years ago) when the climate was warm and moist. The Rocky Mountains then arose a second time during the Oligocene (about 30 million years ago). The mountains intercepted the moisture-laden winds from the Pacific, and caused a rain shadow to the east (Dix 1964). The climate was warm and tropical grasslands, forerunners of modern grasslands, started to develop. Miocene deposits (about 20 million years ago)[4] in Colorado have yielded grass parts that have been assigned to the genus *Stipa* (Gould and Shaw 1983). Grass pollen has been identified numerous times from this same period which confirms this as the period of evolution.

Glaciation

Additional changes occurred during glaciation in the Pleistocene. Four periods of glaciation begin with the Nebraskan about 300,000 years ago. It was followed by the Kansan and the Illinois. The Wisconsin was the most recent, occurring only 10,000 to 60,000 years ago (Dorf 1960). Increasing cold and the slow southward movement of the glaciers caused the wheatgrasses, needlegrasses, and other cool-season species of northern origin to slowly spread to the south and southwest. Upon retreat of the glaciers toward the polar cap during the long, warm, dry interglacial periods, these species moved back northward. But some remained in the south. The warm-season grasses that originated in the southwest and what is now Mexico also moved northward during the interglacial periods. The movement of the glaciers caused the mixing of many species. Numerous relics from glaciation may be seen today. The eastern edge of the Black Hills in South Dakota and the north facing slopes along the Niobrara River in Nebraska contain examples of eastern deciduous forests. Another example is the presence of maples (*Acer* spp.), normally found in the forests of Ohio, in Caddo Canyon in westcentral Oklahoma.

[4]We have difficulty in understanding such long periods of time. Let's consider time-lapse photography to help understand the length of time represented by 20 million years. We will take one frame of film each 25 years. Then we will show the film at the rate of 16 frames/second, or 400 years/second. It would take nearly 14 hours to show the film.

Thermal Maximum

Thermal Maximum occurred from about 7,000 to 4,000 years before the present (Bryson et al. 1970). Temperatures during this period were 1 or 2° C higher than they are today, and warm-season grasses were able to migrate into the northern Great Plains. Some of the cool-season species were eliminated from the southern areas.

Little Ice Age

The Little Ice Age covers the period of 300 to 400 years before the present (Bryson et al. 1970). Temperatures were about 1 degree celcius cooler than in the present. It was the coldest period since man started to record weather conditions. Harbors froze farther south, and the growing season was greatly reduced. Warm-season plants less tolerant of cold and those requiring longer frost-free periods to reproduce were eliminated from the northern Great Plains. This period did not last long enough for cool-season plants to make significant advances southward.

Drought

Drought is a natural part of the environment of the Great Plains. Weakly (1962) constructed a drought history of the Great Plains using dendrochronology. He recorded over 20 droughts of five or more years in duration during the previous 750 years. Scientists are most familiar with the effects of the drought of the 1930s on grasslands (Albertson and Weaver 1942, Weaver and Albertson 1936).

The drought devastated the grasslands. In only seven years, the eastern boundary of the Mixed Prairie moved 100 miles east at the expense of the True Prairie (Weaver 1954). In just two years, one-third of the vegetation in the True Prairie was dead. In some areas, all of the indiangrass and big bluestem were gone, leaving the shorter sideoats grama and blue grama. From 80 to 90% of the plants were lost on some prairies. Losses of taller plants usually caused a chain reaction loss of understory plants. When the taller plants died, the understory plants could not tolerate the heat and light that penetrated the canopy. Losses were greatest where animals were allowed access (Albertson and

Weaver 1942). Not all plants decreased. Western wheatgrass and a few other species increased by utilizing moisture in early spring before most other species began growth.

Much like the warm interglacial periods, the drought of the 1930's permanently changed the vegetation (Stubbendieck et al. 1982). It has not been the same since, and probably will never be. The drought of the 1930's was recorded in tree rings as having a duration of ten years. Of the 21 droughts reported by Weakly (1962), 11 were of longer duration than 10 years. One was 38 years in length. One can only speculate as to the influence that a drought of this duration would have on the native vegetation.

Herbivores

Evolution of Native Herbivores

By the late Paleocene, several families of mammals were largely herbivorous (Van Valen and Sloan 1966). Competition among herbivores for available vegetation was probably a dominant factor controlling the rate of animal evolution. The Miocene Epoch was a period of world-wide upheaval resulting in extinction of many species, and considerable faunal exchange occurred between North America and Eurasia (Simpson 1947). A great diversity of grazing animals are preserved from the Miocene. Teeth of the plains dwelling animals of this time show a change from browsing to grazing. High crowned teeth evolved that continued to grow in response to the wearing of teeth by the grasses, which had a high silica content. Specialization to lengthen stride also occurred (Vaughn 1972).

The Pleiocene was more stable than the Miocene (Kurten 1972). The Great Plains savanna supported three-toed, two-toed, and single-toed horses in addition to camels, elephants, antelope, rhinoceros, and peccaries. The Pleistocene mammals that followed were even more abundant and diverse (Schultz and Martin 1970). It was also a period of faunal interchange between the continents (Simpson 1947). Mammoths became abundant as did deer and bovids.

Just as the current vegetation evolved during the periods of glaciation and interglacial periods, so evolved the grassland fauna as we know it today. Large and rather sudden changes occurred near the end of the Pleistocene (about 11,000 years ago). Horses, giant ground sloths, and mammoths disappeared in a rather short period of time (Martin 1975). The early bison *(Bison occidentalis)* became extinct about 8,000 years ago (McHugh 1972). The reasons are not known. Some feel that it was hunting pressure, but others point out inconsistencies in these theories (Grayson 1977, Martin 1975). The result was a continuing lack of diversity of large grazing mammals which is unlike any other time during evolution. The effect of these extinctions on energy flow will never be known. Probably more energy flows directly to decomposers now than before (Risser et al. 1981). Some herbivores survived and flourished. Bison *(Bison bison)*, elk *(Cervus canadensis)*, mule deer *(Odocoileus hemionus)*, and pronghorn *(Antilocarpa americana)* expanded to the large numbers that early naturalists and travelers saw and described (Allen 1871).

The number of bison on the plains before settlement has been an item of debate among both historians and scientists. Estimates vary from 30 to 125 million (Gunderson 1985, McHugh 1972, Roe 1951). The estimates have decreased as our knowledge of carrying capacities have become more complete.

Numerous other species of herbivores evolved in the grasslands; some to become extinct (McKeena 1969, Shultz and Martin 1970, Van Valen and Sloan 1966). Rodents and lagomorphs, however, were successful and abundant throughout the evolution of the grasslands.

Less information is available about invertebrates. Insects on what is now the Great Plains date from the Permean, but fossil records from the Pleistocene and earlier are not complete. Many diverse species of invertebrates coevolved with the grassland vegetation (Risser et al. 1981, Ross 1970).

Impact of Native Herbivores

Vegetation on the Great Plains evolved under periodic heavy use followed by periods of rest and recovery. Morphology and life history strategies of most grassland species are adapted for survival under grazing pressure from herbivores (Weaver and Clements 1938). However, not all plants of the same life form respond correspondingly to grazing, as has been shown by some of the classic range management research (Dyksterhuis 1949, Smith 1940, Tomanek et al. 1958).

Heavy use by bison was common around watering sites, salt licks, and calving grounds; nonetheless, there were few long-term effects on the vegetation in terms of depletion (Stewart 1936). The herds were nomadic (Roe 1951), and when vegetation was fully utilized on one site, the bison moved to another, allowing it to recover.

Large populations of other mammals and invertebrates also exerted heavy cyclic pressure on the vegetation. When forage was no longer available, they moved or their numbers greatly decreased. Hence, the vegetation received a period of rest during which it recovered. The extinction of many Great Plains herbivores in the Pleistocene is, in the same manner, partially responsible for the period of rest required for recovery of its vegetation.

This is a simplified view of the impact of herbivores. Climatic variables and fire would be prominent factors affecting not only the movements of animals, but also the vegetation. When all of the other factors are combined, the Great Plains ecosystem becomes extremely complex, but it was in balance. An important point is that vegetation on the Great Plains evolved with use. Plant materials did not accumulate on the soil surface for long periods of time. Herbage not consumed by herbivores was consumed by fire.

Human Interactions

Early Man's Impact

Man crossed the Bering Strait into North America during the Wisconsin glacial period. He dispersed across the continent in a few thousand years. Population numbers were never high in most areas of the Great Plains. Were these early inhabitants simply a part of the natural ecosystem? Probably not. They may have been the force for extinction of some animals, but numbers of these animals were probably low when man arrived. Hunting abilities increased with acquisition of horses from Spanish explorers in the 16th century. Many could venture farther into the plains to hunt and live. During the few hundred years they had horses, the American Indians may have killed 3 million bison each year, hardly enough to affect adversely the bison population. But man's extensive use of fire removes him from the category of a biotic factor and places him in the anthropic category.

Great Plains of 150 Years Ago

The Great Plains of 1837 was a broad expanse of grassland. The vegetation was not uniform, but it generally intergraded in wide ecotones. For the most part it was treeless because of the xeric climate and fire. The fauna most notably included large herds of nomadic bison. Other ungulates were common, but not as numerous. Invertebrates flourished in cycles. The soils were still virgin, having not yet felt the bite of a plow. American Indians were relatively numerous in only a few locations. It was a complex, dynamic, natural ecosystem.

Early Explorers, Cattlemen, and Farmers

First and second generation Europeans had been raised in or near forests and did not understand the concept of a broad, treeless prairie. John C. Fremont (1845) reported that the plains were a novelty that excited Asiatic, not American, ideas: "It is difficult to picture those scenes of Asian wilderness within our natural borders. From childhood, we have so linked descriptions of piles of scorial and treeless, grassless slopes with dimmest legends of the olden time that we cannot will persuade ourselves that such things are American realities" (Greene 1856).

Large numbers of settlers first entered the Great Plains after the Civil War. The bison were largely eliminated within 15 to 20 years, partially as a means of controlling the American Indians.

Barbed wire became widely available in the 1870's. Settlers soon fenced their land and left their animals on the range continuously. The vegetation quickly began to deteriorate because it was not allowed to rest after grazing. Numbers of domestic animals were allowed to increase while cultivation removed part of the grazing resource.

The frequent result was deterioration of the vegetation. The domestic animals themselves were not the problem. Domestic livestock did not constitute a new biological process. Their grazing habits were not greatly different than that of the bison. The problem was one of too many animals left continuously on the range without a chance for recovery of the vegetation.

Modern range management developed following the dought of the 1930's. Information gained through research and experience has enabled managers to develop methods to properly utilize the vegetation. Much of the vegetation of the Great Plains has recovered from degraded conditions caused by previous management.

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Establishment of Range Plants in the Northern Great Plains

R. E. Reis, R. S. White and R. J. Lorenz[1]

Abstract.--The 1985 Food Security Act instituted the Conservation Reserve Program (CRP). This program provides economic incentives to plant highly erodible cropland back into grasses, forbs, shrubs or trees. Through the fifth signup, about 3.8 million acres (1.5 million ha) in the Northern Great Plains have been accepted for seeding under CRP. A review of information concerning problems and techniques of establishing range plants in the Northern Plains is provided.

The Great Plains region of North American encompasses the southern Canadian provinces of Manitoba, Saskatchewan, and Alberta, south through the central part of the United States to the Mexican border and the Gulf of Mexico. For this paper, the northern portion of the Great Plains as delineated by Norum et al. (1957) (fig. 1) is considered as the Northern Plains.

Soils of the Northern Plains are composed of chernozem soils on the east, chestnut soils in the center, and brown soils on the west (table 1). Soil depths decrease from east to west (Buckman and Brady 1969).

Climate of this area is distinctly continental. The portion lying east of a north-south line from central North Dakota into Nebraska is considered to be part of the subhumid region of the United States, while the portion west of the same line is considered part of the semiarid region (U.S. Department of Agriculture 1941, Bailey 1980). Average annual precipitation within the Northern Great Plains ranges from 10 to 20 in. (25-51 cm) with approximately 75% occurring during the months of April through September (fig. 2). Mean annual temperatures range from 35 to 50 F (1.7 - 10 C) (fig. 2). Mean annual pan evaporation within the Northern Great Plains increases from a low of 35 in. (89 cm) in the northeast to a high of 65 in. (165 cm) in the southwest (U.S. Department of Commerce 1968) (fig. 2).

The native grassland ecosystem of the Northern Plains developed under the climatic conditions outlined above. Stubbendieck has described the vegetation more completely in these Proceedings. The true tall grass prairie was found in the eastern portion of North Dakota in the Red River Valley (fig. 3). Dominant species included big bluestem *(Andropogon gerardi)*, little bluestem *(Schizachyrium scoparium)*, switchgrass *(Panicum virgatum)*, Indian grass *(Sorghastrum nutans)*, and sideoats grama *(Bouteloua curtipendula)*. The remainder of the region was originally mixed-grass plains (Sims and Coupland 1979) (fig. 3). Major species included blue grama *(Bouteloua gracilis)*, western wheatgrass *(Agropyron smithii)*, needle-and-thread grass *(Stipa comata)*, green needlegrass *(S. viridula)*, buffalograss *(Buchloe dactyloides)*, and prairie junegrass *(Koeleria cristata)*.

The natural vegetation has been greatly altered by man. Only remnants of the true tall-grass prairie are left intermixed with cropland, and part of the mixed grass area has also been plowed for wheat production. In the spring wheat region, characterized by gentle topography (fig. 3), wheat crops are integrated with forage crops for livestock. Depending upon the market price for wheat and livestock, more land is allocated to wheat or cattle in order to increase revenues (Lorenz 1977). The plowing of grass for wheat crops is common when wheat prices are high, followed

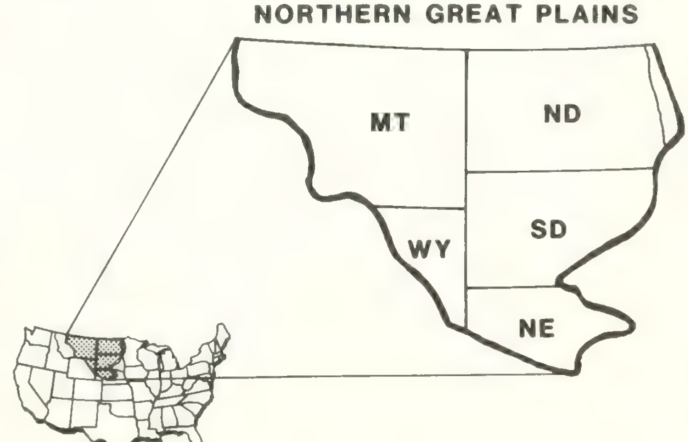

Figure 1.--Northern Great Plains region (after Norum et al. 1957).

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Table 1.--The 1938 soil classification system with approximate equivalents in present classification system.

1938 system	Present system[1]
Chernozems	primarily--Cryoborolls; mesic families of typic and udic subgroups of Argiustolls and Halpustolls; udic subgroups of Argiborolls and Haploborolls.
Chestnut soils	primarily--Frigid families of Argixerolls, Durixerolls, Haploxerolls, and Palexerolls; mesic families of aridic subgroups of Argiustolls, Argixerolls, Haploxerolls, and Haplustolls; typic subgroups of Argiborolls and Haploborolls.
Brown soils	primarily--Mesic families of aridic subgroups of argiustolls, Argixerolls, Haploxerolls, and Haplustrolls; mesic families of ustollic and zerollic subgroups of Argids and Orthids.

[1]*Soil Survey Staff. 1975. Soil Taxonomy. p. 433. Agriculture Handbook No. 436. Washington, D.C.*

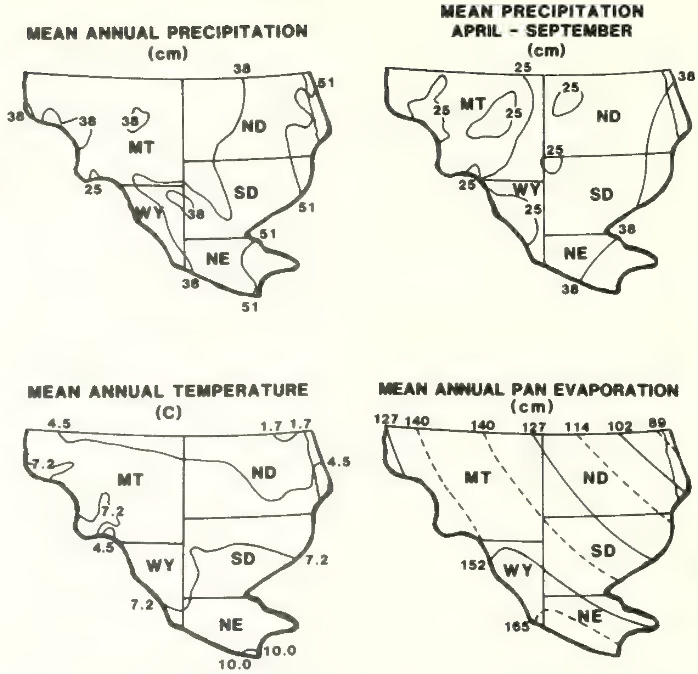

Figure 2.--Climatic summary of the Northern Great Plains (U.S. Department of Agriculture 1941 and U.S. Department of Commerce 1968).

by the reestablishment of grass for forage when livestock prices provide better revenues. In this integrated system, the timely reestablishment of grass is important to protect the soil resource from excessive erosion and to shorten the time required to increase livestock production.

The rangeland region of the Northern Plains has rougher topography and is found in the eastern part of Montana, western South Dakota, and northeastern Wyoming (fig. 3). While some dryland agriculture can be found in this region, the growing season climate is hot and dry and soils are shallow and erodible and, therefore, marginal for crop production. Range plant production for livestock and wildlife appears to be the best land use. Pasture and rangeland are very important in the Northern Plains region because they provide an economic return from these marginal lands. Private pasture and rangelands along with leased public rangeland are operated together to provide economic livestock operations on land with little other economic potential. Currently, more than 100 million acres (40 million ha) over 60% of the total land in the region, are used for pasture and rangeland.[2]

During the late 1970s and early 1980s there was an increase in the conversion of native grassland to cropland within the Northern Plains. The Soil Conservation Service (SCS) in South Dakota recorded the conversion of over 1,033,500 acres (413,400 ha) of native grassland to cropland from July 1, 1974 through June 30, 1986.[3] Since these converted grasslands are often marginal for crop production and can be highly erodible, such land use changes have increased accelerated soil erosion and threatened the productive capacity of these lands for any use. Legislation, commonly known as the 1985 Food Security Act with sodbuster provisions, was recently passed as a means of reducing the conversion of native grasslands to marginal croplands. The Bill also instituted a new program called the Conservation Reserve Program (CRP) which provides economic incentives to plant highly erosive croplands back to grasses, forbs, shrubs, and trees. The main proposed benefit from this program is to conserve the Nation's soil resource.

With the initiation of the CRP, there has been a dramatic increase in grass seedings in the Northern Plains. About 3.8 million acres (1.5 million ha) have been accepted for the CRP through the fifth signup period within this region (personal communication August 1987, with USDA-SCS State Resource

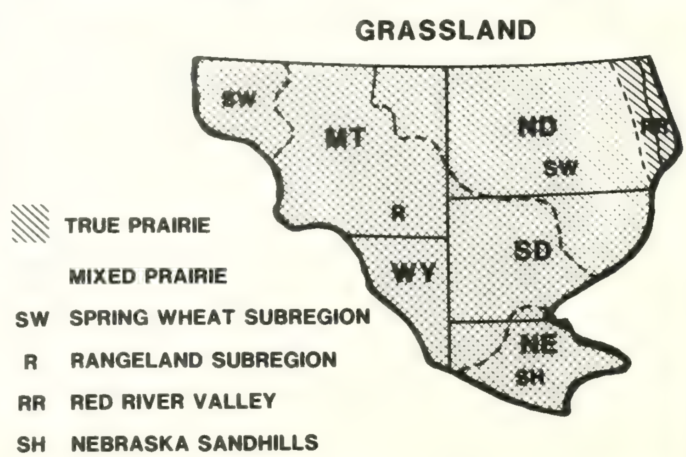

Figure 3.--Original vegetation and land use of the Northern Great Plains (adapted after Sims and Coupland 1979 and Norum et al. 1957).

[2]*U.S. Department of Agriculture. 1987. The Second RCA Appraisal-Public Review Draft. Washington, D.C.*

[3]*U.S. Department of Agriculture, Soil Conservation Service. 1986. Estimated land use conversions, grassland to cropland, July 1, 1985-June 30, 1986, South Dakota, Huron.*

Conservationists--Myron Senechal, ND; Dwayne Breyer, SD; Robert Lohmiller, MT; Lionel Young, WY; and William Hance, NE). This has stimulated demand for more useful information concerning the best techniques for seeding and planting range plants. The purpose of this paper is to discuss principles and techniques for establishing range forage species in the Northern Plains.

Range Plant Establishment

Planning for Seeding

Any seeding effort requires good planning. Items such as the purpose of the new seeding, selection of species, cultivars, or species mixture, and selection of proper seeding methods and time should be considered. Once a plan is formulated it should be carefully executed.

The ultimate use of the seeded plants should determine the plant species to be selected. In the Northern Plains, grasses will be of primary importance, with forbs, shrubs and trees having a secondary role in special situations. There are many plant species and cultivars suitable for seeding or planting in this region. Final selection will be dependent on the specific location where the seeding or planting will take place. Plant species are not equally suited for all environmental conditions or uses; therefore, it is important to select the species and cultivars best suited for the specific use and environment.

Monocultures or a mixture of species may be seeded. Likewise, there is a place for both native and adapted introduced species in seeding. For example, a monoculture of crested wheatgrass *(Agropyron cristatum* or *A. desertorum)* may serve well for early, spring pasture. Alternatively, a broad mixture of slender wheatgrass *(Agropyron trachycaulum)*, western wheatgrass, green needle-grass, sideoats grama, and blue grama may be desired for a diverse stand that will be grazed seasonal-long.

After the species or mixture of species have been selected for a particular seeding, care must be taken to assure the seed obtained is of good quality, weed free, and from a location geographically and environmentally similar to the location where the seeding will be made. Information on plant species adaptation and selection is available in the literature (Vallentine 1980) and from Soil Conservation Service field offices.

Techniques for Seeding Range Plants

Information on seeding and planting techniques has generally been written for specific locations since localized conditions will necessitate slight modification of general techniques. Vallentine (1980) and Decker et al. (1973) have provided broadly applicable general information on seeding and planting techniques. Similar information on a more localized basis for specific parts of the Northern Plains is also available. Short (1943) provided an in-depth discussion of seeding practices in Montana. McWilliams (1955), Dietrich (1965), and Dodds and Meyer (1974) discussed research results and seeding techniques for North Dakota. Lang et al. (1975) discussed techniques for seeding dryland range, pastures, and disturbed land in Wyoming. Derscheid et al. (n.d.) discussed planting tame pasture and hayland in South Dakota.

Seedbed Preparation

The first field operation in any seeding will be seedbed preparation. Seedbeds are often clean-tilled land that is fallowed prior to seeding or clean stubble land. Seedbed preparation can be completed with conventional farming equipment such as plows, disks, or field cultivators. When seeding into clean-tilled land, primary and secondary tillage should result in a weed-free, firm, and relatively smooth seedbed. More rough seedbeds have been used in conjunction with broadcast seeding. Seeding directly into stubble has been a common practice since the 1940s. Seeding into stubble is a desirable technique since it is less expensive, and the stubble and crop residue provide for soil protection from wind and water erosion while new seedings are being established. Stubble seeding methods have been improved by the development of no-till drilling equipment.

However, under certain conditions, yet to be defined, seeded crops and grasses have been adversely affected by this practice. Elliott and Cheng (1987) assessed allelopathy among microbes and plants, and pointed out two ways seeded plants may be affected. First is from the direct production of toxins by microbes, and the second is by toxic molecules produced during microbial decomposition of organic crop residues. Both of these have been difficult to demonstrate, mechanistically. Conclusive evidence is evasive because interacting environmental factors regulating the allelopathic relationship, such as soil water and temperature, are difficult to characterize and incorporate into a model of what really is occurring. McWilliams (1955) seeded grasses into 8 to 10 in. (20 to 25 cm) wheat stubble without seedbed preparation at Mandan, ND in the years 1942 through 1948 and did not report any problem from the residual stubble. As Mitchell and Evans point out in this Proceedings, more detailed information is still needed to understand the situation pertaining to phytotoxins in small grain stubble.

Seeding Methods

Grain or grass drills equipped with depth bands and packer wheels have been by far the most successful means for seeding grasses and forbs in the Northern Plains. Depth bands prevent placement of the seed too deeply into the soil, while packer wheels insure good seed to soil contact. New drills have been developed that improve the accurate seeding of fluffy seed. No-

till drills have made seeding directly into stubble more effective through better seed depth control even through crop residues.

Depth of planting is generally proportional to the size of the seed being planted. Depths of 0.5 in. (1.3 cm) or less have been used for small seeds such as blue grama, while depths of 0.75 to 1.0 in. (1.9 to 2.5 cm) have been used for larger seeds like western wheatgrass. McWilliams (1955) studied planting depths of 0.5, 1.0, and 1.5 in. (1.3, 2.5, and 3.8 cm) for cool-season grasses at Mandan, ND, during the 1940s. He found that the cool-season grasses [crested wheatgrass, western wheatgrass, smooth bromegrass *(Bromus inermis)*, Canada wildrye *(Elymus canadensis)*, Russian wildrye *(E. junceus)*, and green needlegrass] produce satisfactory stands when seeded at depths of 0.5 to 1.0. in. Some species produced better stands when seeded at 1 in. in the spring. Poor stands resulted from all plantings deeper than 1 in. Warm-season grasses were seeded at 0.25, 0.5, 0.75, and 1.0 in. (0.6, 1.3, and 2.5 cm). Satisfactory stands of warm-season grasses (blue grama, sideoats grama, switchgrass, and big bluestem) resulted from planting depths of 0.25 and 0.5 in., but poorer stands resulted from planting depths greater than 1 in.

Drill row spacing has generally varied from 6 to 12 in. (15 to 30 cm). Wider row spacings are generally used in the western part of the Northern Plains where moisture is more limiting. Proper row spacing is important to minimize inter- and intra-species competition for soil water.

In some cases, seedlings have been successfully established when seed was broadcast over an area. However, this method is not generally recommended. Seedbeds for broadcast seeding can be rougher and less firm; hence, this method may be the only feasible way to seed steep, rough areas. Some method of mechanical seed covering, such as the use of a soil drag or cultipacker, is highly recommended for broadcast seeded areas to aid in seed coverage and seed/soil contact.

Interseeding has been used with some success in the Northern Plains. In this method, new species are introduced into existing vegetation by seeding rows of the new species following chemical or mechanical seedbed preparation. This technique has been used to introduce forbs, primarily dryland alfalfa *(Medicago sativa)*, into rangeland communities.

Transplanting plants into localized, prepared areas has been used for shrub and tree plantings. Transplants of bare-root or containerized seedlings of shrubs and trees are costly, but have provided some success in getting these plant groups established on localized, suitable sites.

Seeding Dates

The time of seeding is an important factor to the success of any dryland seeding or planting. Basically, the time should be just prior to the greatest probability for favorable precipitation and temperatures to support plant species germination, emergence, and establishment. Achieving this seeding date is fortuitous in the Northern Plains because of variable weather conditions. Periods of drought can occur during any of the recommended seeding periods and can adversely affect the success of establishment. Usually, cool-season plants can be successfully seeded in fall (September - October) and early spring (April).

Warm-season plants should be seeded from late April to early May. Warm-season grasses established the best stands when seeded between April 20 and May 10, while later plantings resulted in poor stands (McWilliams 1955). Shrubs and trees are also usually planted in late April and early May.

All cool-season grasses, except for western wheatgrass, establish the best stands when seeded in early to mid-September; however, western wheatgrass stands are best when seeded in mid-October (McWilliams 1955).

Seeding Rates

Seeding rates in the Northern Plains vary with local conditions and previous experience of the seeder. Perennial grasses are seeded from 18 to 147 per live seed (pls) per ft.^{2} (200 to 1600 pls m^2). This translates from 5 to 35 lb./ac. (6 to 39 kg/ha). Broadcast seeding requires increased seeding rates.

Seeding rates affect both stand establishment and forage yield of warm- and cool-season grasses (McWilliams 1955). Seeding rates of 8 to 10 lb./ac. (9 to 11 kg/ha) produced satisfactory stands for all species, both in stand establishment and forage yield. Heavier rates 12 to 15 lb./ac. (13 to 17 kg/ha) resulted in forage yield sufficient to warrant their use for green needlegrass.

Early Stand Management

Proper management during and after seeding is crucial to insure success. Unless fertility levels are extremely deficient, fertilization at seeding does not appear to increase stand densities. The addition of nitrogen and phosphorus the second growing season may insure vigorous growing seedlings. Fertilizer must be used carefully, however, because weeds in the stand will become more competitive with fertilizer.

Weed control is sometimes needed to reduce weed competition with the establishing seedlings. Competition for water and light can reduce the success of the new seedlings. Chemicals are available for controlling broadleaf weeds after grass seedlings have emerged or reached a certain leaf stage. Mechanical mowing of the weedy species just above the establishing grass seedlings has also been successful. Cultivation is a common practice around planted shrubs and trees to reduce weed competition. Competition from weeds can be more severe in periods of adverse weather conditions such as low rainfall.

Initially, new seedlings should be protected from livestock grazing. Controlled grazing or haying of stands during the second and third growing season can be done under most circumstances. However, grazing should be carefully controlled so damage to the young seedlings does not occur. Haying of newly seeded stands should occur when the new seedlings have completed their

phenological development in order to lessen damage. Obviously, lands placed in the CRP are not available for haying or grazing during their 10-year contract periods.

When new stands are established, it must be understood that these stands are dynamic and plant succession will take place. Fertilizer application, grazing, mowing, and burning are tools that can be used to improve these initial stands and even change plant species composition as they develop. Fertilizer application or excess residue removal may enhance the vigor of the new stands. Early spring grazing can reduce the cool-season component of a stand in favor of the warm-season species. Likewise, the timely application of nitrogen early in the spring can favor the cool-season species over the warm-season species. The uses of these management tools should not be overlooked when they can enhance the newly developing stands.

This has been an overview of seeding and planting information for range plants in the Northern Plains. While information exists, more detailed research concerning the environmental effect on current seeding methods is needed. Guidelines for plant species selection and seeding and planting techniques for various soils and climatic conditions are available from Soil Conservation Service field offices.

Summary

A review of grass seeding results in the Great Plains was conducted by the Great Plains Council (1966). Data from this report for Resource Areas found in the Northern Plains show that, out of 1390 seedings, 72% resulted in stands with 1.0 or more plants per ft.^{2} (10.8 or more plants per m^2) and 28% had less than this density. This shows that, while seedings are more successful in the Northern Plains than the Central or Southern Plains, failures can still be expected.

In seedings or plantings, every effort should be made to use good planning and proper techniques. Controllable factors are; species and cultivar selection, seed quality, seedbed preparation, seeding method with appropriate rate and depth, seeding date, and early stand management. However, weather conditions are uncontrollable. The best chance to mitigate unfavorable weather is with proper plant species selection and seeding dates that will take advantage of the most probable favorable weather conditions for plant establishment.

No matter what we do, we will have to live with the weather conditions of the semiarid region which encompasses most of the Northern Plains. C. Warren Thornthwaite described it best in the following statement: "In a desert, you know what to expect of the climate and plan accordingly. The same is true of the humid regions. Men have been badly fooled by the semiarid regions because they are sometimes humid, sometimes desert, and sometimes a cross between the two..." This is the situation in most of the Northern Plains area and is of primary importance to successful plant establishment.

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Establishment of Native and Introduced Range Plants in the Central Great Plains

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Abstract.--Successful establishment of grass seedings in the Central Plains is an uncertain process because of low and unreliable precipitation, hot summer temperatures, competition from weeds, and losses due to insects and disease. Proper seedbed preparation and seeding practices can increase the likelihood of establishing a stand of range plants. Standards and specifications used by the Soil Conservation Service for seeding CRP lands are provided.

The Central Great Plains consists of Colorado east of the Rocky Mountains, Western Kansas, Western Nebraska and southwestern Wyoming. This region receives 10 to 22 in. of precipitation annually. Much of the region is marginal for crop production even when using the best agronomic practices. Greb (1979) pointed out that "Just because land is level and east of the Rocky Mountains does not imply that the climate at the place is suitable for sustained dryland agriculture. Some areas are too dry, too warm and too windy too often." The only certainties in the Central Great Plains are wind and recurring drought. These very same climatic factors that make dryland agriculture difficult in this region cause even more serious problems in establishing forage grasses.

During the period 1946 to 1975, failures in dryland wheat plantings averaged from less than 10 percent in portions of the eastern half of the Central Great Plains to over 40% in southeastern Colorado (Greb 1979). Similar data are not available for failures in grass seeding projects; however, our best estimate is that during an equivalent period at least 50% of the grass seedings could be expected to produce a stand of grass that would rate as less than completely satisfactory. Grass seeding failure rates are highest in areas that receive less than 15 in. average annual precipitation and in southeastern Colorado. Failures must be expected because of drought, lack of rainfall during critical growth periods, wind erosion, insects, poor seedbed preparation, weed competition, seed planted too deep or too shallow, seed washed out of deep-furrow drill rows not planted on the contour, wrong date of planting, seeding unadapted varieties, seedling diseases, or more commonly a combination of these factors. Carefully following proper seeding procedures can reduce the number of failures, but it cannot eliminate them, and failures do occur during seemingly ideal conditions.

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Although there are differences in specific regulations of the Conservation Reserve Program (CRP) regarding seeding methods and seedbed preparation among the various states, from the standpoint of general principals, seeding methods and procedures are essentially the same throughout the Central Plains region, and will be discussed for the region as a whole. Some seeding recommendations are site specific, and, in a later part of this paper, will be discussed for each major area within the region.

The Planning Process

Planning is the first and one of the most important steps in any seeding project. Unfortunately, it is a step that is frequently overlooked or not taken seriously. Plans should be detailed on paper, not just kept in mind, and important dates should be marked on the calendar. Planning for CRP projects is further complicated by the need to be aware of all of the applicable regulations and to complete all of the necessary paper work in order to receive full payment under the Program. Because regulations change periodically, one must be certain that only current regulations are followed.

The first step in planning is to determine where adequate financing for the project can be obtained. The exact planting procedures to be followed, the species to be planted, and the post-planting management of the seeding should be determined. Before the project is started, one must be certain that the desired procedures can be completed at the appropriate time, that an adequate supply of the desired varieties of seed will be on hand because seed of many species will be in short supply, and that suitable equipment for seedbed preparation and planting will be available and in good repair.

If a contractor is to do the seeding, arrangements should be made well in advance because the better contractors will have more work than they can readily handle. Fencing may be necessary to protect the seeding from livestock. Arrangements should be made to evaluate the success of the seeding as early in the season as practical and to have a contingency plan available for replanting in case of a stand failure.

Seedbed Preparation

A well prepared seedbed is much more critical for planting grasses than for planting small grains because of the need to precisely control seeding depth of the grasses. Moreover, the grass seedings, because of their relatively low vigor, need optimum soil moisture conditions near the surface for survival. The seedbed needs to be smooth enough to permit accurate depth control when planting the seed. It must be firm enough to provide good soil-seed contact, optimum soil water relations, and to provide support for the depth bands on the drill to prevent the seed from being planted too deeply (McGinnies 1962). At the same time, the seedbed must not be so hard that it prevents adequate penetration by the drill discs.

If possible, the seedbed should not be cultivated immediately before seeding because this will require that it be cultipacked to firm it up before planting. Cultipacking provides an unsatisfactory option because the packing action will also knock down or destroy stubble or mulch. However, where a stubble mulch is permitted, a shallow cultivation may still be the most practical way to control weeds and volunteer grain plants immediately before seeding.

If the seedbed does not already have a stubble on it, it will be necessary to establish one. The principle reasons for having a stubble are to reduce wind erosion and evaporation of water from the soil surface. Grain sorghum, Sudan grass or millet are the most commonly used crops for establishing stubble and should be planted at 10 to 14-in. row spacing. These should be mowed off before seed is formed to leave a standing stubble of about 12 in. Although the use of wheat stubble is restricted in some locations by current regulations, there is no evidence that it is any less satisfactory than other species for stubble. It is entirely satisfactory if some means is used to control the volunteer wheat. Where stubble mulch is permitted, tillage operations should be kept to a minimum and every effort should be made to keep the maximum amount of well-anchored litter on the surface.

The use of a nurse crop, including sweet clover, is not recommended. Nurse crops compete for soil water that would otherwise be available to the grass seedlings, and, thus, are more detrimental than beneficial for stand establishment. Stubble provides adequate protection for the seedbed and seedlings and makes a nurse crop unnecessary.

Weeds should be eliminated from the seedbed before seeding grasses. Weed control is important both for conservation of stored soil water and to avoid later competition with the grass seedlings. Weed control is best accomplished with a contact or pre-emergence herbicide; however, the herbicide must be one that will not leave a residual harmful to the grass seedlings. The Soil Conservation Service (SCS) has had good results with a pre-planting application of Glean, Ally or Roundup.[2] Herbicides can also be used to control volunteer plants in small grain stubble. Where a stubble mulch is to be used, a shallow pre-planting cultivation can be used to eliminate weeds and volunteer grain.

Seeding Techniques

Seeding rates will vary with the species and location, but in general the minimum rate will be near 20 pure live seeds per foot of seeded row (McGinnies 1970). Specific seeding rates for various locations and species will be presented later. Where care is taken in seedbed preparation and seeding technique, seeding rates may be lowered. With the present cost and unavailability of quality grass seed, it is important to do the best possible job of seeding so that the minimum practical seeding rates can be used. It is important to check the seed tag for germination and purity, and to adjust the seeding rate to a pure live seed basis.

Seeding rates are usually expressed as number of pure live seeds per foot of seeded row because this makes calibration of the drill much easier. Calibration can be accomplished by pulling the drill over a hard surface that the discs do not penetrate, counting the number of seeds dropped over a measured distance, and adjusting the drill feed mechanism until the desired rate is obtained. Accurate seeding rate calibration insures that an adequate amount of seed is planted, while at the same time avoids wasting scarce and costly seed.

Because of the small size of most grass seeds and the relatively low seedling vigor of most grass species, accurate control of seeding depths is one of the most critical factors for successful seedings. Generally, grass seed should be planted at least 1/2 in. deep to avoid the rapid soil drying near the surface, but seed should not be planted more than 1 in. deep because many grass seedlings will have difficulty emerging from a deeper depth (McGinnies 1973). Thus, except for special cases, the recommended planting depth for most grass species is 3/4 in. This depth allows for slight variations in seeding depth while still remaining within the 1/2 to 1-in. depth range.

Accurate control of seeding depth is best accomplished with a double-disc drill equipped with depth bands when used on a firm seedbed. If a deep-furrow drill is used, the planting depth in the bottom of the furrow should still be 3/4 of an inch. However, seed planted in a deep furrow may become covered too deeply because of soil sloughing or by wind or water deposited soil. Deep-furrow planting is usually unnecessary if a suitable mulch or stubble is used. Another problem encountered with deep-furrow planting is that if the furrows are not on or near contour, water can run down the furrow and wash out the seed.

[2] The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement of the product by the U.S. Department of Agriculture to the exclusion of others that might be suitable.

Because of the need to plant grass seed with a high level of precision, the importance of using a suitable grass drill cannot be overemphasized. When planting free-flowing seed such as that of crested wheatgrass, a grain drill that uses a flute-feed system and is equipped with double-disc openers and depth bands can do a completely satisfactory job. However, if hairy, fluffy or trashy grass seed, e.g., blue grama *(Bouteloua gracilis)* or the bluestems (*Andropogon* spp.), is to be planted, a special grassland or rangeland drill will be needed. These drills have seed metering mechanisms that will uniformly feed seed that will not feed through a standard grain drill. Most are equipped with more than one seed box; the additional seed boxes meter out free-flowing seed and fine seeds such as legumes or the lovegrasses (*Eragrostis* spp.).

The ideal drill, then, has double-disc openers with depth band and should be capable of accurately delivering the desired rates of all the species to be planted into a wind-proof drop system to the very bottom of the small furrow opened by the discs, and then cover the seed and pack the soil over it with a packer-wheel. If the drill is also to be used for range seeding, it must be of extra sturdy construction. Grassland drills that meet all of these specifications are available from commercial sources.

While the modern grassland drill is capable of planting grass seed with great precision, it cannot accurately control planting depth when pulled at excessive speeds. These drills are designed to be operated at 3 to 3-1/2 miles per hour. The maximum speed at which they should be used is 4 miles per hour. At higher speeds, precision seeding is almost impossible. Four miles per hour is a very fast walking speed, so if one cannot readily walk along side of the drill when planting, the drill is going too fast. Contracts for seeding should specify that all drilling is to be done at speeds of less than 4 miles per hour.

Broadcast seeding is not recommended. If for some reason broadcast seeding must be used, seeding rates should be doubled or tripled, and some method must be used to cover the seed. The biggest problem with broadcast seeding is that it does not accurately control the planting depth of the seed. Most culti-packer-type seeders would be classified as broadcast seeders.

The ideal row spacing for most grass seeding in the Central Plains is 10 to 14 in. If the seeding is planted to a bunchgrass that is later to be harvested for hay, row spacings up to 18 in. may be an advantage because the wider row spacing will usually produce taller plants that are easier to harvest. Row spacings of less than 10 in. can result in low-growing plants that are more susceptible to drought damage.

If a grass-legume mixture is to be planted, it is best to seed the legume in alternate rows with the grasses (McGinnies and Townsend 1983). The grasses should be seeded at a 16 to 28-in. spacing with the legumes seeded between the rows of grass. This can be accomplished using a drill with 8 to 14-in. spacing and plugging every other seed drop in the grass box and then plugging the alternate drops in the legume box. If necessary, grasses and legumes can be seeded in the same row, but the alternate row system is preferred.

Applying fertilizer at the time of seeding is not recommended. Nitrogen fertilizer will encourage weed growth and the weeds will compete even more strongly with the grass seedings. One exception to this generality is where alfalfa will be planted on soils with a low phosphorus content. Under such conditions, it is usually desirable to add phosphorus.

Post-emergence weed control can be a great aid to seedling establishment, particularly if done early in the season before weeds can utilize available soil water (McGinnies 1968). Broadleaf weeds are readily controlled with 2,4-D; however, 2,4-D obviously cannot be used if a legume has been included in the seeded mixture. Spraying with 2,4-D will usually not damage grasses if the grass seedlings are past the three-leaf stage. In general, 2,4-D will not give satisfactory weed control unless the soil is moist and the weeds are growing vigorously. Mowing weeds may be of limited help, but generally by the time weeds are large enough to mow, they have probably already used up much of the soil water.

The seedling stand should also be watched for evidence of insect damage. Pesticide application may be necessary where substantial damage is possible. Particular attention should be given to the Russian wheat aphid in wheatgrass (*Agropyron* spp.) seedings particularly after it reaches maturity. As a general rule, if more than 10 to 20% of the plants become infested, a spray program to control the aphid should be initiated.

Effects of Temperature, Precipitation on Seedling Establishment

When selecting a seeding date, consideration must be given to species, soil moisture, seasonal precipitation, mulch cover, weed control and equipment availability. Rangeland and non-irrigated cropland seedings in the Central Plains are risky in any given year due to unpredictable precipitation patterns and hot summer temperatures common throughout this area. However, new technology and methods have added alternatives that were not available 20 years ago, including new cultivars with increased seedling vigor and herbicides for weed control.

Effective precipitation and frequency of rainfall events are of great concern when establishing plants. Research indicates two events of at least 0.2 in. within 2 to 5 days are generally required for germination with adequate soil temperatures. Less than 0.2 in. is of little significance due to rapid evaporation. After emergence, precipitation is needed within an estimated 5 to 8 days or seedlings will not survive. This period decreases to approximately 2 to 4 days when surface soil temperatures are above 90 F. As a result, the periodic 10 to 14 day dry periods common throughout the Central Plains cause a significant loss of seedlings.

In addition to precipitation, soil temperatures are critical for germination of some warm season grasses. Blue grama requires a soil temperature of 60 F at seed depth for good germination and it germinates more rapidly at higher temperatures (Wilson and Briske 1978). Other species, such as alkali sacaton *(Sporobolus*

Table 1.--Optimum germination temperatures for selected grass species as measured on a temperature gradient plate (from Sabo et al. 1979).

Species	Temp (°F)	Time (hrs)	Temp (°F)	Time (hrs)	Const. temp (°F)
Sand dropseed[1] *(Sporobolus cryptandrus)*	32	8	67	16	
Western wheatgrass[1] *(Agropyron smithii)*	50	16	65	8	
Sideoats grama *(Bouteloua curtipendula)*	53	8	88	16	73
Little bluestem *(Schizachyrium scoparius)*	61	16	81	8	
Galleta *(Hilaria jamesii)*	--	--	--	--	84
Blue grama *(Bouteloua gracilis)*	90	8	97°	16	

[1]*Light reported to be necessary.*

airoides) and Western wheatgrass *(Agropyron smithii)*, germinate at lower temperatures while galleta *(Hilaria jamesii)* favors warmer soil temperatures, as noted in table 1. In eastern Colorado, temperatures should be adequate for seed germination of warm season species by the latter part of April. Surface soils usually are relatively dry in early spring and warm up quickly with warm days. Cool season grass species will germinate at lower temperatures, provided adequate soil moisture is available.

Seed emergence studies (Wester and Dahl 1983) at Lubbock, Texas, show best emergence of sideoats grama *(Bouteloua curtipendula)* with consecutive days of at least 0.2 in. precipitation and a soil temperature of 86 F. Seedlings under these greenhouse conditions emerged in 2 days. At temperatures of 75 F and 63 F, emergence occurred in 4.2 and 7 days, respectively. No plants germinated at soil temperatures above 100 F even with 0.6 in. of water applied over 3 days. The soil apparently dried too rapidly.

Seedling establishment of blue grama requires two properly spaced periods of damp, cloudy weather - one for emergence and one for development of adventitious roots. These periods of cloudy, wet days need to be spaced about 2 to 6 weeks apart. The seedlings seldom survive longer than 6 weeks without adventitious roots (Wilson and Briske 1979), and they recover from drought-induced stress only if they have developed such roots (Wilson and Briske 1978). The largest number of adventitious roots were initiated at 68 F and two or more consecutive wet days (Briske and Wilson 1977). Adventitious roots are also needed for winter survival of Blue grama.

It may be unrealistic to predict successful seedings with best known cultural methods during years of below normal precipitation. However, climatic data can be used to select the seasons when precipitation probability is the greatest and temperatures are adequate. Evaporation or effective precipitation must also be considered as temperature increases.

Generally, seeding as early in the spring as possible is best, particularly with cool season species (McGinnies 1973). Research at Manhatten and Hays, Kansas indicate that March 15 through May 15 is the best time to seed warm season native grasses (Launchbaugh and Anderson 1963). Better seedling survival was obtained from planting prior to May 1 in southwestern Kansas (Schumacher and Atkins 1965). June and July seeding, not recommended in southeastern Colorado, has shown variable results; however, it may be successful with certain precipitation patterns.

Standards and Specifications

Standards and specifications for seeding CRP lands have generally been developed on a state by state basis. SCS standards and specifications for seeding have been used with modifications to adapt for local needs and for requirements of other agencies such as the Colorado Division of Wildlife and the Agricultural Stabilization and Conservation Service. The SCS Range Seeding and Pasture and Hayland Seeding Standards and Specifications are generally used to regulate most CRP acreage seeding in the Central Plains.

The standards used depend on which practices (CP-1, permanent introduced grasses and legumes; CP-2, permanent native grasses; CP-3, tree planting; CP-4, wildlife habitat; CP-5, field wind break; etc.) are applied. In Colorado and Kansas, CP-2 is the major practice applied, while in Wyoming it is CP-1 and in Nebraska it is dominantly CP-4.

Tables 2, 3 and 4 highlight the main items from SCS State Range Seeding Standards and Specifications.

It is important to use the proper cultivar or strain of plant material. Released cultivars have been selected for improved characteristics. Using the proper cultivar may be just as important as selecting the right species. A brief summary of common varieties used in the Central Plains is provided in table 5.

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Table 2.--Summary of SCS standards and specifications for range seeding, seeding depth, date and rate.

Location	Date	Rate (seeds/ft.)	Depth (in.)
Colorado	Warm season species		
Eastern Plains	Nov 1-May 20 southern Oct 15-May 20 northern	20	1/2-1 (2-3 Indian Ricegrass)
	Cool season species		
	Nov 1-Apr 30		
Kansas	March 15-May 15 (Opt.)	22-25	1/4-3/4
Western Plains	Dec 1-May 15 (Max)		
Wyoming	Warm season species	(Ave 20)	1/2-3/4 (light soils)
(Southeastern)	Early Spring-May 15		
	Cool season species		
	dormant-Apr 15	14-40	1/4-1/2 (heavy soils)
Nebraska	Warm season species		
(Western)	Nov 1-May 31 Mar 15-May 15 (Opt)	20 (min)	1/4-1
	Cool season species		
	Aug 1-Sept 15 and Nov 1-Apr 15		

Table 3.--Summary of standards and specifications for range seeding, cover crops.

Location	Planted cover crop	Residual cover crop
Colorado Eastern Plains	Forage & Grain Sorghum Sudan Broomcorn (18 in. ht.)	Sorghum, Sudan Broomcorn, Millet Wheat (9 mo. old)
Kansas Western Plains	Forage Sorghum Grain Sorghum Small grains (oats, wheat) (12 in. ht.)	Surface mulch essential
Wyoming (Southeastern)	Spring Grain (10 in. PPT +) Sorghums Sudangras Foxtail Millet	Stubble (free of weeds and volunteer)
Nebraska (Western)	Grain Sorghum Forage Sorghums Hybrid Sudangrass (May require 2 or more years) (12 in. ht.)	Sorghum Corn Stubble Millet (Broomcorn) (12 in. ht.)

Table 4.--Summary of SCS standards and specifications for range seeding, weed control, planting methods, row width.

Location	Method	Row width (in.)	Weed control
Colorado Eastern Plains	Drill Interseeder Airseeder	7 - 12 Interseeder < 42	Herbicides Mowed
Kansas Western Plains	Drill Broadcast (BDCT discourages)	------	Herbicides Mowed Graxing (Not CRP)
Wyoming (Southeastern)	Drill or Grass seeder Interseeder	up to 24 linterseeder	Herbicides Clippings 4" min. Shred
Nebraska (Western)	Drill Interseeder	------- < 42" row	Herbicides Mowed Shred

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Table 5.--Summary of major grass varieties recommended for central Great Plains.

NATIVE

Species/Cultivar	Recommended CO KS WY NE	Source	Released	Outstanding characteristics
Big Bluestem	*(Andropogan gerardii)*			
Champ	WY NE	NE ARS	1963	Maturity 10 days earlier than Pawnee, sandy soils
Kaw	CO KS NE	KS Ex. Stn.	1950	Flint hills, tall, resist to rust
Pawnee	KS NE	NE	1963	Late maturity - orig Pawnee, Co. NE
Little Bluestem	*(Schizachyrium scoparius)*			
Aldous	KS NE	KS	1966	Orig Flint hills, leafy, some rust resistance
Camper	NE	NE	1973	Breeders selected for Kansas and Nebraska
Cimarron	CO KS WY NE	KS	1979	Assembled from KS, S. E. CO, NM, and OK Panhandle
Pastura	CO WY	NM	1963	Seedling vigor, seed production
Blaze	KS NE	NE	1967	Adapted to central and N.E. NE
Sand Bluestem	*(Andropogan gerardii var. hallii)*			
Champ	CO NE			
Elida	CO	NM	1963	Seed production, seedling vigor
Garden	KS WY NE	NE	1960	Winter hardy, vigorous, tall, leafy
Goldstrike	WY NE			
Woodward	CO KS	OK	1955	Seed production, high yields
Blue Grama	*(Bouteloua gracilis)*			
Lovington	CO KS WY NE	NM	1963	Uniform, leafy, seedling vigor
Hachita	CO KS	NM	1980	Vigorous, drought hardy, robust
Sideoats Grama	*(Bouteloua curtipendula)*			
Haskel	CO	TX	1983	Seedling vigor, high yield
Butte	CO WY NE	NE	1958	Winter hardy, northern range, good seedling vigor
El Reno	KS	OK	1944	Leafy high forage and seed yields
Niner	CO	NM	1984	Seedling vigor, tall, high production
Pierre	WY NE	ND		Seedling vigor, leafy
Trailway	NE	NE	1958	Late maturing, rust free
Vaughn	CO WY	NM	1940	Seedling vigor, drought tolerant
Buffalograss	*(Buchloe dactyloides)*			
Texoka	KS		1974	High seed potential
Improved	KS			Available prior to Texoka
Greenneedle	*(Stipa viridula)*			
Lodorm	WY			
Indiangrass	*(Sorghastrum nutans)*			
Cheyenne	CO KS	OK	1954	Good seed and forage yields
Holt	NE	NE	1960	Early maturity, fine leaves
Llano	CO	NM	1963	Leafy, high seed yields

(continued)

Table 5.--*(continued)*.

NATIVE

Species/Cultivar	Recommended CO KS WY NE	Source	Released	Outstanding characteristics
Osage	KS	KS, OK	1966	Tall, vigorous, leafy late maturity
Oto	NE	NE, KS	1970	Long season variety, erect robust
Nebraska 54	KS NE	NE	1957	Tall, leafy, high seed yields, good seedling vigor
Prairie Sandreed	*(Calamovilfa longifolia)*			
Goshen	CO KS WY NE	WY	1976	High forage yields, drought hardy, mildly rhizomatous
Sand Lovegrass	*(Eragrostis trichodes)*			
Nebraska 27	CO NE	NE	1949	Winter hardy, palatable
Bend	CO KS	OK, KS	1971	Uniform maturity, good establishment
Prairie Sandreed	*(Calamovilfa longifolia)*			
Goshen	CO KS WY NE	WY	1976	High forage yields, drought hardy, mildly rhizomatous
Sand Lovegrass	*(Eragrostis trichodes)*			
Nebraska 27	CO NE	NE	1949	Winter hardy, palatable
Bend	CO KS	OK, KS	1971	Uniform maturity, good establishment
Switchgrass	*(Panicum virgatum)*			
Blackwell	KS NE	OK	1944	Upland type, leafy, high yielding
Kanlow	KS	OK	1963	Tall, Coarse, productive, low land
Nebraska 28	CO WY NB	NB	1949	Early maturity, susceptible to rust
Pathfinder	NE	NE	1967	Winter hardy, leafy, late maturing, rust resistant
Slender Wheat	*(Agropyron trachycaulum)*			
Revenue	NE	Canada	1970	Salt tolerant, high seed and forage yields
San Luis	CO	CO	1984	Good seedling vigor, longlived, tall, robust
Thickspike Wheatgrass	*(Agropyron dasystachyum)*			
Critana	CO WY	MT	1971	Vigorous sod, drought hardy
Western Wheatgrass	*(Agropyron smithii)*			
Arriba	CO WY	CO	1973	Vigorous seedling, spreader
Barton	CO KS WY NE	KS	1970	Vigorous seedling, spreader
Flintlock	NE			
Rosana	CO W	MT	1972	Palatable, tight sod, seed production
Old World Bluestem	*(Bothriochloa ischaemum/caucasicus)*			
Ganada	CO KS	USSR	1979	Cold tolerant
Iron Master	KS		1987	Doesn't show iron deficiency

(continued)

Table 5.--*(continued).*

NATIVE Species/Cultivar	Recommended CO KS WY NE	Source	Released	Outstanding characteristics
WW Spar	KS		1985	Seedling vigor, increased production
El Kan	KS	KS	1955	Increased seed production
Smooth Brome	*(Bromus inermis)*			
Manchara	CO WY	China	1943	Wide area adaptation, strong sod, cold tolerant
Lincoln	CO WY	NB	1942	Production, establishment
Tall Fescue	*(Festuca arundinacea)*			
Alta	CO KS NE	OR	1940	Winter hardy, high yield
Kenmont	KS NE	KY	1963	High yield, dense sode, adapted in MT
Fawn	KS NE	OR	1964	High protein, seed yield, spring vigor, high yield
Weeping Lovegrass	*(Eragrostis curvula)*			
VNS	KS NE			

(continued)

Table 5.--*(continued).*

NATIVE Species/Cultivar	Recommended CO KS WY NE	Source	Released	Outstanding characteristics
Crested Wheatgrass	*(Agropyron cristatum/desertorum)*			
Ephraim	CO WY	Turkey	1983	Seedling vigor, sod former, seed yield
Nordan	CO WY	ND	1953	Seedling vigor, robust growth
Hycrest	CO WY	USSR	1984	Hybred, seedling vigor, high yielding
Intermediate Wheatgrass	*(Agropyron intermedium)*			
Oahe	CO WY	SD	1961	High seed and forage, rust resistance
Amur	CO	China	1952	High production, leafy, seedling vigor
Pubescent Wheatgrass	*(Agropyron trichophorum)*			
Luna	CO WY	USSR	1963	Drought tolerant, seedling vigor, high yields

Range Plant Establishment in the Southern Plains Region

Bill E. Dahl, Paul F. Cotter, David B. Wester and Carlton M. Britton[1]

Abstract.--Failure to establish seeded stands is most commonly due to patterns of rainfall, inadequate seedbed preparation, and failure to sufficiently remove competing vegetation. Most frustrating of stand failures are those resulting from enough moisture to germinate seeds but when follow up moisture comes too late for seedling establishment. Soils of the region are especially susceptible to wind erosion, making the preparatory crop method more desirable here than in other regions. These crop residues also reduce soil temperatures, help control weeds, and reduce evaporation - all critically needed in the hot climate of the Southern Plains. Weeping lovegrass, sideoats grama, blue grama, switchgrass and old world bluestems are species most commonly seeded on Southern Plains ranges.

Not since the "Soil Bank" era have we seen as much interest in grass seeds, seed production, wild seed harvest, seeding equipment, and techniques on how to seed semi-arid cropland or eroding land. Of course, this has been triggered by the advent of the Conservation Reserve Program (CRP) contained in the 1985 Farm Bill. Under this program the federal government is essentially "renting" highly erodible cropland for 10 years from farmers and ranchers, and requiring this rented land be planted to permanent vegetation. Already, after only one planting season, seed supplies are nearly exhausted and those wishing to plant are competing for any kind of available seed. Inevitably, much of this land will be seeded to species ill-adapted to the land being seeded.

Regardless of the reason to seed areas to grass, one should ideally plan the initial planting as a long term investment. Some of the questions that should be asked when choosing among potentially available species are given here as a planning guide: Is the species you have chosen adapted to your soil? Is seed available at a reasonable cost? How soon will you need to use it? What is the risk of seeding failure? How long will the seeding last? Will new fences be required? Will water be available for grazing animals? Is wildlife use, (e.g. upland game birds), an important consideration? What are the management requirements? What kind of livestock or wildlife will use it? Is stand establishment technology and the necessary equipment available? Will this seeding benefit your overall goals and objectives? How will this seeding fill existing gaps in your current grazing management scheme? Is irrigation a possibility? Will you want to harvest seed from this stand? Above all, have you sufficiently checked the costs and expected returns to find out if your chosen seeding program has a reasonable chance of returning a profit?

A range revegetation program requires more advance planning than most operators realize. This report is designed to answer some of the common questions relative to revegetating marginal and eroding cropland in West Texas.

Failure to obtain a successful seeded stand is most commonly due to one or more of the following items: (1) lack of rain at the proper time; (2) inadequate seedbed preparation; (3) improper seeding depth; (4) weed competition; (5) seeding at the wrong time of the year; (6) insect and rodent damage; (7) species not adapted; (8) poor quality seed; (9) improper equipment; and (10) lack of grazing protection until stand establishment. Thus, successful seedings depend on the attention devoted to the above items.

Climate and Timing

In the Southern Plains, range seeding is only recommended where annual precipitation averages 11 in. or more. Seeding failures commonly occur from rain of 0.5 in. or less that germinate planted seed but follow-up rain that is needed in 4 or

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5 days comes too late to allow survival of new seedlings. Unfortunately, most rainfall events in semiarid climates below 24 in. of annual precipitation in the Southern Plains are less than 0.4 in. per event. Thus, we suggest planting just prior to the most consistent rainfall period that has favorable temperatures for seed germination.

Most of the Southern Plains has from 12 to 24 in. of annual precipitation. The most consistent rainfall comes during the last 10 days of April through May and again in September and October. Thus, warm season species should be seeded in April and May. Cool season species are seeded in April or, preferably, in August and September. While seedlings of warm season species from June plantings occasionally survive, high temperatures and inconsistent rainfall make this a risky period without availability of irrigation water to insure seedling establishment. Experience has indicated that seedlings from late October plantings seldom survive the winter due to the low probability of receiving sufficient rainfall.

Soils

All plants useful for permanent pasture do well on intermediate soil textures, i.e. sandy loams, silts, and loams. However, few do as well on the clays, clay loams, loamy sands, and sands. Those that grow well on the coarse textured soils cannot tolerate clay soils and vice-versa. Other soil conditions requiring careful species selection are high salinity, alkalinity, and high water tables that preclude adequate soil aeration.

The following discussion gives results of our testing of those species thought most useful for seeding west Texas croplands to permanent forage. Seven high yielding grasses were evaluated on the High Plains of Texas on three soils of varying texture. Grasses tested were Blackwell switchgrass *(Panicum virgatum)*, El Reno sideoats grama *(Bouteloua curtipendula)*, Morpa weeping lovegrass *(Eragrostis curvula)*, and four old world bluestems (*Andropogon* spp.) which included Caucasian, WW spar, Ganada, and WW517. Row spacing width was 40 in. and seeding rate was 65 pure live seed per ft. The soils were an Acuff loam (clay loam range site) at Lubbock, an Amarillo loamy fine sand (sandy land range site) at Brownfield, and a Brownfield fine sand (deep sand range site) near Post, Texas. Brownfield and Post are located about 35 mi. southwest and southeast of Lubbock, respectively.

Establishment of all species was highest at the sandy land range site near Brownfield. It had an average within-row basal cover of 55%. Basal cover at Lubbock and Post was 49% and 18%, respectively. Switchgrass, sideoats grama, and weeping lovegrass were the easiest to establish during a year with good soil moisture. However, all species provided acceptable stands. During a year with less favorable precipitation, switchgrass and sideoats were easiest to establish.

The highest yields were at Lubbock, probably due to a substantially higher soil nitrogen level. All species yielded about 8,000 lb./acre except sideoats grama and Ganada old world bluestem. They produced about 5,000 lb/acre during favorable conditions. In a dry year, switchgrass and WW517 produced twice the yield of the other species. At Brownfield, similar trends were evident except the yields were less than half those measured at Lubbock. Yields at Post were lowest of the three areas with weeping lovegrass the only species producing appreciable forage on this deep sand site.

Considering all factors, including response to fertilization and defoliation, weeping lovegrass yielded best on the sandier soils and WW517 performed best on the heavier soils. Switchgrass could be used to extend the green feed period longer into the summer months.

Planting Methods

Bare soil can be vegetated by sprigging (vegetative transplants) or seeding (broadcasting or drilling seed). Sprigging is commonly used only where sufficient natural rainfall occurs to give a reasonable chance for plant survival. Even then, it is usually limited to sandy soils. Sprigging has not been shown to have any advantage over traditional seeding techniques on central and west Texas ranges.

For seeding bare soil areas, drilling is preferred to broadcasting on terrain suitable for the operation of machinery. Drilling distributes the seed more uniformly and places it at a proper depth. A few companies manufacture drills specifically to handle the array of small, fluffy seeds of range grasses adapted to the west Texas area. Ordinary grain drills with small seed boxes in good repair will handle some of the small, clean seeds, but depth control is often a problem on such drills. Desirable characteristics of rangeland drills are:

1. Ability to traverse rocks and brush with minimum breakage;
2. Separate seed boxes for small, large, and fluffy (trashy) seeds;
3. Agitator in the seedbox to prevent trash bridging over the seeder openings;
4. Precise metering of seed;
5. Seedbox baffles to maintain seed distribution in the box;
6. Disk openers with band-type depth regulators;
7. Flexible individual planters to adjust to irregular seedbed; and
8. A mechanism for rapid and accurate setting of seeding rates.

On areas with well prepared seedbeds, the grass seeder-packer is a type of drill without furrow openers that provides excellent grass stands. These planters consist of a seeder box mounted over one or more cultipackers that pack the soil about 0.5 in. deep over the seed. Others have also been called "till-and-

pack" drills. This method of planting has been the most consistently successful method of grass establishment in the semidesert grasslands of the Southern Plains when preceded by a pitting operation to conserve soil water.

Any method that scatters seed directly on the soil surface without soil coverage is termed broadcasting. Two types of equipment are commonly used; hydroseeders which apply the seed mixed in water, and fan or air blast seeders. Airplane seeding and hand seeding are also common ways to do broadcast seeding. The seed, however spread, must be covered with soil in some way if it is to become established after germination. This is especially true in desert areas, in arid foothills soils, or on unfavorable sites such as south and west facing slopes at higher elevations. In all cases, broadcast seed covered with soil is much superior to no coverage of seed, especially on sites with rough, cloddy surfaces.

Seed can be covered with harrows, discs, home-made drags, or small sheeps-foot rollers. Running a small tracked vehicle over the area after seeding also may cover the seed satisfactorily. For small areas, driving a tractor over the area such that all portions of the seeded area are disturbed by its tracks is an excellent way to cover the seed as well as provide desirable soil compaction around the seed.

Seedbed Preparation

Several methods of seedbed preparation have been successfully used in range seeding. They are: (1) mechanical methods; including clean tillage and summer fallow; (2) preparatory crop method; and (3) herbicidal methods.

Mechanical Seedbed Preparation

Equipment commonly used for seedbed preparation on rangeland include: disk turning plows; moldboard plows; pitters; modified chains (disk chain, dixie chain, railroad chain); disk plow; wheatland disk plow; brushland disk plow; and offset disk. Most of these create weed-free seedbeds that can result in severe erosion on the sandier soils. Wind erosion not only blows out seed and seedlings in some spots and buries it in others, but it can also shear off young plants by sandblasting. Blowing soil is less of a problem on the more clayey soils.

A major problem in mechanical seedbed preparation has been loose, soft soil that interferes with proper placement of seed and has poor water-holding capacity. Firm seedbeds hold moisture near the surface, help control depth of seeding, and provide anchorage for seedling roots. Rolling before drilling usually improves seed placement and gives better seedling emergence. However, rolling after drilling is generally detrimental. Also, seedbeds compacted and smoothed by rolling are more subject to wind and water erosion.

Small diameter rollers often skid rather than roll, thereby increasing soil density and possibly reducing water intake. Flexible cultipackers are better able to adapt to uneven terrain than flat rollers, give greater packing action below the seed placement zone, and leave a soil surface more suitable for seeding. Drag harrows and rod weeders are also useful for smoothing and compacting where surface trash is not excessive.

Rolling and cultipacking are only successful when existing soil moisture is sufficient for germination and seedling emergence. This is seldom possible in the semi-arid Southern Plains because surface drying is too rapid to allow moisture retention. Whether to use rolling or cultipacking should be decided at the time of seeding based on the conditions of the seedbed. On medium to fine textured soils in the arid portions of the Southern Plains (i.e., less than 12 in. of annual rainfall), seedbed preparation should include pits, basins, or interrupted furrows to catch and hold moisture as an effective technique for achieving good stands. Eccentric disks and other types of pitting machines have been successfully used. Seedings made in the basins have the advantage of extra soil water for germination and establishment. Such practices are usually ineffective on sandy soils.

Preparatory Crop Method

The preparatory crop method involves plowing followed by planting a residue-producing crop during the growing season before seeding perennial forages, and then seeding directly into the residue without further seedbed preparation. Prevention of erosion, reduction of soil temperatures, control of weeds, and reduced evaporation are potential benefits achieved from preparatory cropping. Crops most commonly used for this purpose are sudangrass, other sorghums, and millet.

Winter cereal crops have generally not been as useful as the sorghums. However, winter wheat is a common cover crop for seeding in Oklahoma where old world bluestems are to be planted. The wheat is either grazed out or killed with herbicide the following spring before it can utilize moisture prior to seeding. This technique has also been commonly recommended for weeping lovegrass establishment in the Lubbock area.

Success of the preparatory crop method depends largely on the degree of weed control achieved during the growing of the crop. In one study in which forage sorghum was the preparatory crop, sandburs (*Cenchrus* sp.) were not successfully controlled. Seeding into the sorghum stubble the next year was totally unsuccessful because of intense competition from the sandburs. Other seedbed techniques which controlled the sandburs provided successful stand establishment for the desired species.

Chemical Seedbed Preparation

Chemical seedbed preparation and direct seeding into the killed mulch without further soil treatment is effective if the herbicide, (1) controls a broad spectrum of undesirable plants, (2) dissipates rapidly after weed control is accomplished, and (3) is broken down or leached away by the time seeded species germinate or is not toxic to seedlings. Despite the obvious

advantages of chemical weed control in preparing seedbeds, results are often disappointing because of ineffective control of the existing vegetation. No single chemical is yet available which completely kills all resident plants and also dissipates rapidly afterward.

Herbicides[2] used with varying degrees of success on rangeland plantings are paraquat, glyphosate, dalapon, atrazine, propazine, amino triazole, disodium methanearsonate (DSMA), and siduron and picloram in combination. These include both preemergence and postemergence herbicides.

Fertilization

Fertilizing to aid stand establishment at time of seeding is a hotly contested subject. Most researchers working in semi-arid to arid climates find that adding fertilizer at seeding time usually enhances weed growth, and consequently, competition with the seeded species. If fertilizer is deemed necessary, it is usually better to wait until the seeded species have at least one growing season to become established.

Seeding Rates

The seeding operation should provide adequate seed for a good stand while preventing waste of seed. Increased rates of seeding are suggested for poor seedbeds. When broadcasting, more seed should be used; the usual recommendation is twice the drilling rate. Low seeding rates usually require longer periods of protection for complete stand development, whereas moderate rates are best to produce a full stand within a reasonable time. Range seedings are now commonly done in the Southern Plains on the basis of number of pure live seeds (PLS) per square foot. Seeding rates based on 30 pure live seeds per square foot have become standard for seeding grasses on upland range sites.

Seeding rates may be increased on sites having high production potential. Seeding rates should be adjusted for individual species and seedbed conditions where research and local experience have shown this to be desirable. The quantity of seed should be increased by 50 to 100% on more critical sites such as west and south slopes. Seeding rates are also commonly increased 50 to 100% on more productive bottomland or irrigated sites. If one desires to seed with rows wide enough to allow for cultivation (e.g. 24 to 40-in. rows), 20 to 30 PLS per foot of row should provide an adequate stand.

Planting Depth

The ideal seeding depth for grass seeds is about 1/4 in. for small seed such as lovegrasses, 1/2 in. for average sized seed such as pubescent wheatgrass *(Agropyron trichophorum)*, and 1 in. for very large seeds such as tall wheatgrass *(A. elongatum)* Since all species potentially useful in west Texas are small seeded, seeding depths should be no greater than 1/2 in. Depth bands on disc opener drills are commonly 5/8 to 3/4 in., which places seeds about 1/4 to 3/4 in. deep.

Row Width

Row widths of 10 to 14 in. are most commonly used in range seedings. However, numerous research reports indicate that total herbage production in the Southern Plains is not generally affected by row widths between 6 and 18 in. after full establishment.

Trends of higher yields with narrow spacing immediately after establishment to no difference or higher yields from wider spacing in later years have been reported. Rows spaced 40 inches apart to allow for cultivation have yielded as much forage as more closely spaced rows. However, such spacing tends to increase the proportion of reproductive shoots which some find objectionable for grazing purposes. The advantage is obvious to those interested in raising grass seed.

Germination Requirements

Our research shows that many species used for west Texas plantings require two applications of water for seed germination and seedling emergence. Weeping lovegrass, kleingrass *(Panicum coloratum)*, and possibly the old world bluestems are examples. An inch or more of rain germinated only a few seeds in some of our field plantings if follow-up rain was delayed more than 4 or 5 days. However, as little as 0.2 in. per day for two days would germinate almost all seeds.

Apparently, many seeds imbibe enough water to start the germination process but because of rapid soil surface drying, they do not retain enough to fully germinate the seed. If a second wetting of at least 0.2 in. occur within 3 or 4 days, the seeds will germinate and emerge as a seedling. If the second rainfall event does not occur within the four or five days, these seeds will again require two applications of water for germination.

Once the seedlings emerge, there must be sufficient soil water in the rooting zone to allow for seedling survival. Seedlings usually die within 5 or 6 days in the Southern Plains once the soil has dried. Seedling survival, will also occur if there is sufficient water to wet the soil several inches deep in the rainfall events that provided for germination. Otherwise, a followup rainfall event must occur within 4 or 5 days after seedling emergence. With this kind of information, we are better able to judge whether our planted seeds have mostly germinated and died, or whether the rainfall events have been too far apart to fully germinate the seeds.

[2]The use of trade company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

Stand Establishment With Irrigation

Many west Texas farmers still have the ability to irrigate part or all of the land they intend to plant to permanent forage. As described above, enough rainfall to germinate seeds is commonly received, but followup rain comes too late for seedling survival. Therefore, having the means to assure adequate soil water at these critical times can often mean the difference between stand establishment or failure.

A suggested scenario for someone with irrigation potential is to dry plant on a well prepared, weed free seedbed, then wait for natural rainfall of at least 0.25 inch. When it is possible to irrigate, preferably the day after natural rainfall, begin applying a moderate amount of water, e.g., 1-inch. This both provides the second watering required to fully germinate planted seeds and it assures enough soil moisture for seedling survival. Unless the summer is unusually dry, natural rainfall should keep the seedlings alive once they are established. Amounts of water applied should be greater than a comparable natural rainfall event due to higher and more rapid evaporation. Unless natural rainfall provides one watering, two irrigations will be required for seedling establishment. The two waterings should not be more than 4 days apart. A large field may have to be seeded in segments if it is not possible to irrigate it all in 4 days.

What is an Acceptable Stand?

For range seedings, we like to have at least one established seedling per square foot or per foot of row if rows are spaced more than 1 ft. apart. Realistically, a successful planting can occur with much less than that. Uniformity is more important than plant density. In the Southern Plains, one established perennial plant per square yard will eventually produce all of the forage most sites are capable of producing. Therefore, if one or more seedlings can be found for every step when walking through a seeding, a successful stand should result.

Buying Seed

Range grass seed is typically trashy and fluffy with only a small fraction of actual seed in the material put through the planter. Because the amount of actual seed varies widely among seed lots of the same species, seeds are sold on a PLS basis. This means that every seed lot has to be tested for purity. By law, seed labels are required to give the amount of pure seed, seed germinability, the amount of other seed, date of the germination test, and where the seed was grown. For example, if a lot of seed is 80% pure seed and the germination is 50%, then for every 100 lb. of bulk material you get, you have 80 lb. of seed (designated PS). Since it is 50% viable you have 40 lb. of pure live seed (designated PLS). Percent purity multiplied by percent germination gives PLS. It is also preferable that the origin of the seed is local enough to be adapted to the particular climate where it is planted.

Weed Control During Establishment

In semi-arid and arid climates of the Southern Plains, weed prevention is more important than weed control after seedling emergence. Grassy weeds, e.g. sandburs, Japanese brome *(Bromus japonicus)*, and foxtail grasses (*Setaria* spp.) are particularly difficult to control in grass plantings. Most herbicides that kill the grassy weeds also kill the seedlings. We find that a cleanly tilled crop stubble (preparatory crop or dead litter mulch method) gives a relatively weed-free seedbed. Also, early fall seedbed preparation for small grains often gives excellent weed control as germinating weed seeds do not overwinter or do not compete well with the small grain crop.

For newly prepared, clean tilled seedbeds, moldboard plowing produces much better weed control than tandem discing. The top soil and weed seeds are buried by plowing and nutrients are brought to the surface resulting in more vigorous seedlings. Discing mixes the weed seeds and the organic matter in the soil surface without burying it. With discing, decaying organic matter also ties up many of the nutrients needed by the planted seeds. Because discing is much cheaper than plowing, we have found that discing early in the spring, waiting for sufficient rainfall to germinate the weed seeds, then lightly rediscing before planting, provides satisfactory weed control. Any of the contact herbicides may be used in place of the second discing. Broadleaf weed herbicides[3], such as 2,4-D and Banvel, can be used on most grass seedlings after they have 4 or 5 leaves. Recommended dosages should be followed, with application taking place before the weeds become very large.

Erosion Control

Much of the western Southern Plains has soils subject to severe wind erosion. The preparatory crop method, described earlier, constitutes the best means to reduce erosion during stand establishment. When this is not feasible, unplowed strips should be placed perpendicularly to the prevailing wind, especially on highly erodible sandy soils. The main criterion in controlling wind erosion is to prevent the wind from accelerating near the ground across a large unprotected plowed field, a process known as avalanching. To prevent this, relatively narrow strips of vegetation (which may be weeds) should be left while the seeded portion of the field is becoming established. Unplowed strips of 10-20 ft. interspersed with 30-50 ft. plowed and planted strips provide some wind protection. Given favorable weather, one should then be able to plow and plant the windbreak strips the following year.

Establishment of Shrubs and Forbs in the Southern Plains Region

Darrell N. Ueckert[1]

Abstract.--Establishing palatable shrubs and/or forbs in mixtures with grasses is ecologically sound and can improve the value of revegetated areas for wildlife and livestock. Shrubs and forbs that appear to have the greatest potential in the Southern Plains include fourwing saltbush, littleleaf leadtree, winterfat, Maximillian sunflower, and Illinois bundleflower.

The value of shrubs as a plant resource is widely recognized (Blaisdell and Holmgren 1984, Hyder 1973, McKell 1975, Tiedemann et al. 1984, Scifres et al. 1985). There is currently worldwide interest in the use of shrubs for (1) improving the productivity of arid and semiarid rangeland and marginal cropland, (2) alternative crops and emergency drought forage, (3) soil and water conservation, and (4) wildlife habitat improvement. Range scientists and resource managers in the western United States have used shrubs for improving the quality of livestock diets and rangeland productivity (Gade and Provenza 1986). Recent research suggests that several species of shrubs have potential for use in the Southern Plains region (Ueckert 1985). Following is a discussion of three such species.

FOURWING SALTBUSH

Fourwing saltbush *(Atriplex canescens)* has the greatest potential for use on Conservation Reserve Program (CRP) lands in the Southern Plains. The species has been recognized as valuable for rangeland livestock and wildlife for many years because of its abundance, wide area of adaptation, evergreen habit, palatability, and nutritive value (USDA Forest Service 1937). It is salt tolerant and very drought tolerant, often thriving in arid regions having less than 10 in. annual precipitation. Fourwing saltbush has a deep tap root and an extensive, shallow, fibrous root system. It occurs naturally from the Central Plains westward into California, and from northern Mexico to southern Canada. Potential of the species as a cultivated crop was recognized by the beginning of this century.

Fourwing saltbush has substantial growth potential in semiarid areas of the Southern Plains. For example, total standing crop in a west Texas site receiving 15 in. annual precipitation averaged 15,000 lb./ac. within 16 months after seeding (McFarland et al. 1987). The estimated net annual production of 2.5-year old fourwing saltbush plants growing under cultivation on 6 ft. spacings in rows 6 ft. apart near San Angelo, Texas, averaged about 6,000 lb./ac. (Petersen et al. 1987).

Value of Fourwing Saltbush for Grazing

Fourwing saltbush is relatively palatable and maintains high levels of crude protein throughout the year (Soltero and Fierro 1980). It is particularly valuable as browse during the winter for both livestock and wildlife (Springfield 1970). For example, average mid-December values for crude protein, phosphorus, and in-vitro digestible organic matter for the saltbush leaves in one study were 17.9%, 0.14%, and 59%, respectively (Petersen et al. 1987). Winter crude protein does vary, however, among some accessions or ecotypes of fourwing saltbush because of differential retention of winter leaves (Welch and Monsen 1981).

Fourwing saltbush is an important component of livestock diets where the shrubs are abundant (Shoop et al. 1985). Livestock grazing rangelands where fourwing saltbush is abundant have been shown to require very little supplemental feed (Gonzales 1972). In western Texas, an acre of fourwing saltbush might provide the supplemental crude protein requirements for about one animal unit of livestock for a three-month period (Peterson et al. 1987).

Fourwing saltbush alone, or in mixtures with grasses, can provide diets of sufficient quality to produce weight gains of yearling sheep and yearling Angora goats during winter. In southwestern Texas yearling Rambouillet ewes gained about 10 lb./head grazing a fourwing saltbush-sideoats grama *(Bouteloua curtipendula)* mixture, compared to losing 3 lb./head grazing

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dormant WW-Spar bluestem *(Bothriochloa ischaemum)*, during a 60-day grazing trial in 1987. However, data from a spring feeding trial and an autumn grazing trial suggest that fourwing saltbush browse has a lower nutritional value for young Angora goats than would be expected based on laboratory nutrient analyses (Huston and Ueckert 1986).

Fourwing saltbush plants are not harmed by severe defoliation during the winter. In Texas, stands grazed to near 100% defoliation during winter with sheep and goats for several successive years still provided vigorous spring regrowth in early March and were completely refoliated by June. Defoliation during winter followed by deferment in spring and early summer appears to actually stimulate browse production. Saltbush stands should always be deferred during the spring and early summer following heavy winter grazing.

Establishing Fourwing Saltbush

Seeding

Establishing fourwing saltbush by seeding in arid and semiarid areas has been erratic (Leckenby and Toweill 1983). Major constraints include: (1) poor seed quality (poor fruit fill, low germinability, and resultant low seedling vigor) and inadequate seed quantity; (2) inadequate soil water contents at the seed-soil interface during periods of optimal temperatures for germination; (3) effects of interspecific competition on seedling survival, establishment, and growth; and (4) grazing of the seedlings by wildlife, livestock, or insects.

Adequate soil water during periods when temperatures are optimal for seed germination are essential for establishing stands of fourwing saltbush (Springfield 1970). In western Texas, it is better to seed during late summer and autumn than during spring. Saltbush seed must be in close contact with moist soil for 7 to 14 days for germination and emergence, hence multiple rainfall events are usually necessary for seedling establishment.

Methods of seeding fourwing saltbush and modifying the seedbed for water conservation have been thoroughly researched and reviewed (Stevens and Van Epps 1984). It is critical that the germplasm in seeds purchased for planting be adapted to the area to be planted (Petersen et al. 1987). Seeds should be planted at a depth of 0.5 to 1.0 in. in firm, well-prepared seedbeds. Seeding rates as low as 2 lb. per acre are adequate if a drill with double disk openers and depth bands is used. Seeding rates should be greater (4 - 8 lb./ac.) if seedbed preparation is less than optimal or if the seed is broadcast and covered by cultipacking.

Rows of fourwing saltbush should be at least 10 ft. apart for monocultures. About 100 ft.^{2} per mature plant is an ideal spacing in areas receiving 15 to 20 in. annual precipitation.

Contour furrowing, mulching, pitting, and basins or catchments improve emergence and establishment of seeded shrubs in more arid parts of the Southern Plains (Springfield 1970). However, mulching did not improve establishment or yields of seeded fourwing saltbush in a semi-arid area of western Texas (McFarland et al. 1987).

Drilling fourwing saltbush seed in the bottom of furrows is not recommended because rainfall moves soil downward from the slopes of the furrows and results in excessive seeding depths. Seedling emergence was 4 to 10 times greater following drilling on firm, flat seedbeds compared to drilling in the bottoms of furrows in two experiments in western Texas (D. N. Ueckert, unpublished data).

Transplanting

Transplanting of container-grown fourwing saltbush seedlings is the surest way to attain a successful stand of the shrubs and rapid development of vigorous plants (Petersen et al. 1986). Seedlings can easily be grown in a greenhouse in small containers and are available commercially. Seedlings should be about 6 months old before being transplanted. They should be planted into a well-prepared seedbed that is moist to a depth of at least 1 ft.

Transplanting is much more expensive than seeding, hence it is likely to be an acceptable alternative only for producers who want only a few rows or clumps of shrubs, such as for upland game habitat improvement. Transplanting may also be a means for establishing a few fourwing saltbush plants for seed production and subsequent natural regeneration. Transplanted shrubs begin producing seeds during their second or third growing season in western Texas.

Weed Control

Many fourwing saltbush seedings that have been properly installed have failed to establish because of severe competition from forbs and grasses (Petersen et al. 1986, Van Epps and McKell 1983).

Herbicides have been used to a limited extent for weed and grass control in fourwing saltbush seed orchards, but shrub responses and herbicide efficacy were not reported (Noller et al. 1984). Established stands of fourwing saltbush have not been damaged by broadcast sprays of clopyralid[2] applied at rates that kill susceptible woody plants (Jacoby et al. 1981). Three-month-old, greenhouse-grown seedlings were tolerant of pre-plant soil applications of trifuluralin and oryzalin; however, they were killed by atrazine (Petersen and Ueckert, unpublished data).

Cultivation might be a viable alternative for weed control in shrub plantings on CRP acreage. Cultivation would be possible if the saltbush is planted in rows at least 10 ft. apart, or in single rows 3 - 4 ft. from the closest grass rows. Cultivation may not be feasible for several months after planting because the saltbush

[2] The use of trade and company names is for the benefit of the reader; such use does not constitute and official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

seedlings normally emerge and grow more slowly than the associated forbs and grasses and the saltbush rows may not be discernible. Weed control is usually not necessary after the shrubs are 1 1/2 to 2 ft. tall.

Grass - Shrub Mixtures vs. Monocultures

Fourwing saltbush may be successfully established by planting the seed in mixtures with various grasses. However, the shrubs develop very slowly and many die because of the competition. Therefore, if rapid establishment and production of vigorous fourwing saltbush stands is the objective, grass - saltbush mixtures should not be planted within a drill row. The best procedure is to plant alternating strips of saltbush and grass. Grasses should not be planted within 3 - 4 ft. of the closest row of saltbush. Width of grass and saltbush strips can be adjusted to satisfy the producer's objectives and to be compatible with available planting equipment. It is important to know that fourwing saltbush seedlings initially grow very slowly and that they are easily killed by competing vegetation (Peterson et al. 1986).

LITTLELEAF LEADTREE

Littleleaf leadtree *(Leucaena retusa)* is a deciduous legume with characteristics similar to the closely related koa haole *(L. leucocephala)*, a widely used forage plant in the tropics. The plant can grow to a height of 15 ft., or be maintained in a shrubby growth form by frequent browsing or pruning. It is readily browsed by livestock and wildlife (Lamb 1975). The species is endemic to dry, well-drained, rocky soils in central and western Texas and in Coahuila, Mexico and is fairly drought tolerant.

Littleleaf leadtree will shed some of its leaves during extended hot, dry periods, but the plants produce new flushes of foliage with each significant rainfall event during the growing season. The species is relatively rare on rangelands because of its high palatability and low competitive ability of the seedlings.

The species loses its leaves after frost, but it appears promising for providing high quality forage during dry summer and early autumn periods. Littleleaf leadtree should be considered for use only in the more southerly areas of the Southern Plains since its ability to tolerate low temperatures has not been documented.

Value of Littleleaf Leadtree for Grazing

The forage of littleleaf leadtree is similar in quality to alfalfa hay. Crude protein contents of the forage averaged 21% and in-vitro digestible organic matter averaged about 67% during May through November (Whisenant et al. 1985). Yearling Rambouillet ewes grazing monocultures of littleleaf leadtree during the autumn gained 0.23 lb./head/day in one unpublished western Texas study. There is evidence that good stands of littleleaf leadtree might produce adequate forage to carry 10 to 13 lambs/ac. for 30-day, intensive grazing periods.

Unlike koa haole leaves, which contain up to 12% mimosine, a toxic amino acid, leaves of littleleaf leadtree contain only about 1-2% mimosine. No clinical or pathological signs of mimosine toxicity have been observed in Angora billy kids or Rambouillet ewe lambs grazing pure diets of littleleaf leadtree for 30- to 34-day periods.

Establishing and Managing Littleleaf Leadtree

Intensive management may be essential to successfully establish littleleaf leadtree from seed or containerized seedlings. The seedlings die readily or become severely stunted if competing forbs and grasses are not controlled. Seedlings are also very susceptible to being killed by insects and rabbits. Its seeds have an impervious seed coat that must be scarified for optimal germination. Untreated seeds exhibited only 6% germination compared to greater than 90% germination for seeds that had been effectively scarified in boiling water for 10 seconds or concentrated sulfuric acid for 20 to 30 minutes. It has been recommended that unscarified seeds be planted in the autumn or that scarified seeds, or a mixture of scarified and unscarified seeds, be planted in the spring (Whisenant et al. 1985). Littleleaf leadtree seeds should be planted about 1 in. deep in well-prepared seedbeds. Rows of littleleaf leadtree should be spaced about 8 to 10 ft. apart. Seeding rate should be adequate to establish at least one plant per 3 ft. of row. Close spacing of plants should aid in encouraging the shrub growth form.

The plants exhibit very rapid growth after establishment and should be either grazed heavily or pruned to a 2-feet height each winter to maintain them in the shrub growth form for optimal availability of browse for grazing. The plants will usually have a single-stemmed growth form until they have been pruned back. Pruning stimulates basal sprouting from dormant buds along the lower stems.

WINTERFAT

Winterfat *(Ceratoides lanata)* is a low-growing evergreen shrub that is endemic from northern Mexico to Canada and from the western Great Plains westward to California. It is widely recognized for furnishing palatable and nutritious browse for both livestock and big game animals (Blaisdell and Holmgren 1984).

Winterfat is high in crude protein during winter months (Davis 1979), and utilization as great as 80% during this time does not adversely affect its vigor (Hodgkinson 1975). Utilization greater than 25% in the growing season does diminish vigor of the shrubs, however (Stevens et al. 1977).

Winterfat is adapted to a wide array of soil types, but is most common on calcareous, limey soils. It is highly drought tolerant, with a deep tap root and shallow, fibrous root system. It domi-

nates extensive rangeland areas where annual precipitation is less than 10 in., and extends into subalpine areas where annual precipitation is as great as 40 in. (Stevens et al. 1977).

Seeds of winterfat are commercially available. The seeds lose viability within 2 or 3 years after harvest, so seed should not be stored for longer than 2 years. Seeds should be planted at a depth of 0.1 to 0.5 in. in very firm, well-prepared seedbeds shortly prior to the period during the growing season with highest probability of rainfall (Wasser 1982). Winterfat seed should be planted in separate rows from grasses. Survival and growth of winterfat seedlings are greatly reduced in the presence of competing vegetation (Van Epps and McKell 1983).

PERENNIAL FORBS

Several other perennial plants that are not shrubs have characteristics desirable for use on CRP acreage. Maximillian sunflower *(Helianthus maximiliani)* is a native, perennial forb that grows to a height of 3 to 9 ft. It is best adapted to depressions or other areas that are seasonally moist in the more southerly areas receiving at least 19 in. of annual precipitation. The seeds are choice food for quail and dove, and the forage is palatable to deer and cattle. Seed should be planted 0.25 to 0.5 in. deep during the spring.

Illinois bundleflower *(Desmanthus illinoensis)* is a warm-season, perennial legume with woody lower stems. It is adapted to upland and bottomland sites with clay soils in areas receiving over 15 in. of annual precipitation. The species occurs naturally from central Texas northward well into the Central and Northern Plains. Illinois bundleflower seeds are excellent food for quail, dove, and turkey, and deer readily browse the plants. Seeds should be planted 0.5 to 0.75 in. deep during spring.

CONCLUSION

Establishing shrubs and desirable forbs on converted cropland in the CRP could provide potentially valuable wildlife habitat during and subsequent to the 10-year program, as well as a valuable grazing resource for livestock after it ends. Establishment of shrub or forb plantings or mixtures of shrubs, forbs, and grasses on CRP acreage would appear to be a desirable option for producers whose long-term objective is to permanently convert a portion of their cropland into wildland, wildlife habitat, or grazing land. Planting woody shrubs would obviously not be a viable alternative to those who would likely return the land to crop production after ten years.

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Social and Economic Impacts of the Conservation Reserve Program

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Abstract.--Approximately 23 million acres have been enrolled in CRP during 1986 and 1987. The average accepted bid of $48 per acre will require more than $1 billion in federal funds annually for rental payments. These payments have positive economic impacts for local communities, but other impacts are negative. There are many uncertainties about economic and social impacts and about the future of CRP itself. Like many government programs, the actual results may be far from the intended results. If problems can be detected early, mid-course corrections may facilitate desired outcomes.

The CRP Program

Title XII of the Food Security Act of 1985 initiated several conservation policies and programs including Sodbuster (Subtitle B), Swampbuster (Subtitle C), and the Conservation Reserve Program (CRP) (Subtitle D). Conservation benefits from the CRP include a reduction in erosion and sedimentation, improvement in water quality, and improvement in wildlife habitat. Other projected benefits are a reduction in commodity production, and, thereby, a reduction of ongoing commodity programs and an increase in commodity prices.

Land owners who enroll in CRP enter a ten-year contract with the government to convert highly erodible cropland to permanent vegetative cover. The government will make annual rental payments, in cash or commodities, for the life of the contract; will cover half of the expense to establish permanent cover; and will provide technical assistance. The annual rental payment per acre is determined by a bid submitted by the land owner, which may be accepted or rejected by the government. The total goal for CRP is to enroll 45 million acres of highly erodible cropland over a five-year period. Land under contract may not be harvested or grazed, although fee hunting is permitted.

There are nine acceptable practices under CRP which include (1) establishment of introduced grasses and legumes, (2) establishment of native species, (3) tree planting, (4) establishment of permanent wildlife habitat, (5) field windbreak establishment, (6) diversions, (7) erosion control structures, (8) grass waterways, and (9) shallow areas for wildlife. The majority of land presently in the program will be planted to introduced or native grasses and legumes, cover species for wildlife habitat, and trees (except Christmas trees are prohibited). Most bids that have included tree planting have been in southern states. Proposals accepted into CRP have included 1.25 million acres for tree planting.

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In the first two years of the program, almost 23 million acres nationally have been accepted in the five sign-up periods, which is more than 50% of the 5-year goal (table 1). Accepted bids went as high as $90 per acre while the average rental rate was $48.40 per acre. Over one-half of this acreage is in the Great Plains (Colorado, Kansas, Montana, Nebraska, North Dakota, Oklahoma, South Dakota and Texas), with Texas leading the nation with 2.8 million acres. Enrollment in CRP has declined in Colorado during the last two sign-up periods, possibly due to maximum allowable acreages being reached in several southeastern counties.

Economic Impacts and Concerns

Economics has had an influence on the CRP from the beginning. Low commodity prices and costs of other USDA programs were major reasons for CRP. From the start, farmers and ranchers have been concerned with estimating bids that would at least break even with alternative uses of the land. Factors that influenced the bid amount were the cost of establishing permanent cover, cost sharing with USDA, the value of crops formerly grown on the land, and the payments from participation in other agricultural programs. Establishment costs included expenses associated with establishing a cover crop, seedbed preparation, seed and planting, weed control, and maintenance.

Table 1.--Conservation Reserve Program acreages and average bids for Colorado and the United States through 1987.

Sign up period	Colorado		United States	
	Acres (1,000's)	Aver. bid ($/ac)	Acres (1,000's)	Aver. bid ($/ac)
1	97.67	35.55	838.36	41.82
2	496.42	38.85	3,000.68	40.07
3	467.76	40.69	5,091.62	46.94
4	360.71	43.16	10,572.40	51.17
5	188.91	43.06	5,288.69	47.90
Total	1,611.47	40.60	22,996.00[1]	48.40

[1] Sign up total does not equal the sum of the individual sign-ups as sign-up acreages were taken from initial sign-up summaries which may have had errors and which did not exclude accepted bids that were not contracted. Total came from summary information after the fifth sign-up.

Cost-sharing for permanent cover establishment is limited to those costs incurred in the establishment of permanent cover and does not include annual maintenance costs. Minimum standards and acceptable practices are determined by a committee within each state. The original goal for 1986 and 1987 sign-ups of 15 million acres was exceeded by 8 million acres. Because seed reserves were limited at the start of CRP, annual seed harvest has been the major source of seed for the program. Seed demands have increased seed prices dramatically. Original bids that were based on imperfect knowledge of future seed prices may have been low in many cases.

There are numerous opinions on the economic impacts that the program will have over its 15-year life and beyond. A positive impact within any community is the initial expenditure for establishing permanent cover on CRP lands. For example, if an average cost of $50 per acre for cover establishment is assumed, over $80 million will be spent in the initial establishment efforts in Colorado. Also important will be the annual rental payments to farmers and ranchers. Rental payments in Colorado, paid over a 10-year period, will be $650 million on 1.6 million acres. Total annual payments for land already accepted into CRP will exceed $1 billion nationally.

The $48 per acre average annual rental is a net return to the individual, which may exceed the net realized from cropping highly erodible lands. Also, the bid rental is a constant amount for 10 years, while returns from crops are highly variable, depending largely on weather and market prices. The resultant incentive for enrollment of considerable acreage has had an impact on land prices. In Baca County, Colorado, rental under CRP for summer-fallow wheat land was almost 3 times cash rent, and for row-crop land 1.5 times cash rent (Reichenberger 1987). Thus, a market has been created for highly erodible land that is presently enrolled in or eligible for CRP. In some cases, the high rental rates under CRP have resulted in higher land prices.

A significant negative impact will be the reduced sales by agribusinesses as farmers' needs for chemicals, equipment, fuels and other items used in crop production decline. To minimize this impact, not more than 25% of the cropland in a county can be enrolled in CRP "except that the Secretary may exceed the limitation established ... in a county to the extent that the Secretary determines that such action would not adversely affect the local economy of such county." This limit has been exceeded in some counties. In Colorado, 10 counties had reached or exceeded the limit by the fifth sign-up period, and three more are expected to reach it in the next sign up in February 1988.

The reduced payments from other farm programs is also mentioned as a negative impact on local communities. Currently, these payments are significant in counties where production of wheat and feed grains is important. Reduced deficiency payments, for example, should be recognized in the impact estimates.

Other Programs

There are other components in Title XII that may impact plowing of CRP lands. The Sodbuster subtitle provides that, if highly erodible land is plowed for annual crops without an approved conservation plan, producers are ineligible to participate in any USDA program, including CRP. Thus, plowing these lands may be economically unfavorable for many producers. Similarly, the Swampbuster provides for loss of program benefits if wetlands are plowed for crop production.

The Conservation Compliance subtitle provides that lands cultivated prior to enactment of the 1985 Act, which are found to be highly erodible, must be protected by an approved conservation system by 1995, if eligibility for government benefits is to be continued. There are no guarantees that conservation compliance will be in force in 1996 or that there will be farm programs that would significantly impact producers currently participating in CRP. As Reichenberger (1987) pointed out, "Economic climate a decade from now may not warrant participation in a farm program, if indeed one even exists at that time."

The Future

There is uncertainty as to what will happen after the 10-year contracts expire. Many remember the Soil Bank in which lands that were in the program were again plowed in the 1970's when crop prices increased. In fact, much of the acreage that is in CRP was in the Soil Bank. So these same erodible lands may again be plowed in the future if a profit can be made.

Eligibility for government programs depends on conservative use of plowed CRP lands. An approved conservation system must be in place so that the program benefits are not lost.

Supporters of CRP argue that there were no requirements on land entered in the Soil Bank regarding erodibility, so that not just highly erodible lands were enrolled. However, basic economic

theory suggests that only the marginal land would be enrolled in either the Soil Bank or CRP as the more productive land would still earn more in crop production.

Land can be used in livestock production after expiration of the contract period. But there are questions about what the condition of the permanent cover might be after 10 years of nonuse, and there is concern about impacts that increased forage resources may have on livestock numbers and the livestock industry. Protection of newly established vegetation is provided by the prohibition against grazing during the contract period. But subsequent use for livestock production is not regulated.

Use of established cover by wildlife is permitted, even encouraged, by agencies concerned with fish and wildlife habitat. New plants (e.g. trees) must be protected from damage by rodents; but grass, trees, and water may be used by birds and animals for food and cover without restriction. Fee recreation, using CRP lands, may become a valuable source of income on some farms and ranches.

Obviously, there are uncertainties with this program. Only those that enter the program before Oct. 1, 1987 will be assured of funding. After that date, funding becomes a part of the regular USDA budget appropriations process. Also, as less marginal lands are entered to meet the 45 million acre target, acceptance of higher rental bids or other incentives will be necessary to meet the 45 million acre goal. This was demonstrated in the fourth sign up with the Corn Bonus, which was an added incentive to enroll corn acreage. Total payment for this one-time adjustment to CRP was $340 million and added acreage in the Corn Belt. Over 1 million acres were enrolled in the program in Iowa alone.

Because of the uncertainties, it will be beneficial to monitor the CRP, and study the actual impacts on erosion and sedimentation, crop production, farm operations, and economic viability of rural communities. Like many government programs, the actual results may be far from the intended results. If problems can be detected early, it may be possible to make mid-course corrections that will facilitate desired outcomes. The papers to follow should give good ideas on future possibilities and factors that we should monitor to determine those futures.

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Overview of the Present Land-use Situation and the Anticipated Ecological Impacts of Program Implementation

James B. Newman[1]

Abstract.--A 45-million-acre Conservation Reserve Program will reduce cropland by 25.2 million acres (15%) and erosion by 639 million tons per year while increasing herbaceous cover by 24 million acres (7%). These benefits will accrue as long as the acreage remains in permanent cover.

The purpose of this paper is to provide an overview of the land use picture in the Great Plains prior to the initiation of the Conservation Reserve Program (CRP), project the change that will occur in this pattern and to discuss the related ecological impacts. With complete data available from the first four sign-ups and some data from the fifth sign-up just completed in July, trends are readily available. The paper assumes that current trends will remain constant until the program reaches the 45 million acre goal. This is an acceptable assumption; however, significant variations from the goal could actually occur. For example, during the fifth sign-up, the Great Plains acres accepted in the program jumped from 54% to 64% of the total. If this increase should continue, the projections in this paper will be quite conservative. Therefore, it appears safe to say that at a minimum, the discussed changes will occur.

Background

The ecology of the Great Plains has been discussed by previous speakers at some length. It has been described as unique in that it is continuously exposed to climatic extremes of temperature and low precipitation. The area is characterized by high winds and plagued with frequent drought. The soils formed under these conditions are relatively shallow, but productive with adequate moisture, and very susceptible to soil erosion and degradation. Recovery from soil loss is geologically slow. Thus, it is paramount that the existing top soil and its inherent productive capacity be protected and retained.

The stability of the Great Plains ecosystem with its delicate soil, water, plant and animal relationships is a major challenge confronting us today, tomorrow and on into the future. Under the best soil, climatic and topographic combinations possible, the protective herbaceous and or woody plant cover on the soil surface varies from excellent to very sparse. In areas like the Badlands of South Dakota, with minimal natural cover, natural geologic erosion occurs at a high rate. While in other areas with more amenable climate and soils, such as the tallgrass prairie, geologic erosion is negligible if the plant communities are maintained in a healthy ecological condition. However, even in these areas of the Great Plains, the natural cover is easy to abuse and lose, or to destroy directly with modern machinery. It is also unpredictable, costly, and exasperatingly slow to re-establish.

Once the natural protective cover is destroyed, the destruction of the soil resource follows rapidly, reducing or destroying forever the inherent capability to naturally regain or maintain the protective cover it had prior to the degradation.

Yet, the people, the government, and the landowners and users continue to forget, give low priority or overlook this fragile ecological balance. A cycle of destroying the sod and exposing the bare Plains to the destructive forces of wind and water has developed. This is followed by a period of alarmed, conscientious concern and attempts to re-establish a permanent vegetative cover.

The first near destruction of the Great Plains started in the late 1920's, culminating in the dust bowl of the 1930's. This plowout can probably be credited to the lack of knowledge of the fragile ecosystem, but can also be associated with an ill-conceived land settlement program. The result was an unstable environment and mass abandonment of acres of bare soil to the forces of nature. The government set to work and seeded millions of acres back to herbaceous vegetation. Species selection was determined by cost and availability of seed. Little, if any, consideration was given to ecological compatibility with the soil and the original vegeta-

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tion. Many of these Land Utilization (LU) seedings scattered throughout the Plains remain today as monuments to man's mistake.

Round two started abut 30 years later in the mid-1950's. One could argue this mental lapse was triggered by a manipulated farm economy which sent out a signal of guaranteed grain prices. Whatever the cause, the result was another near disastrous plowout of millions of acres of the Plains and the subsequent establishment of the Soil Bank and Great Plains Conservation Program by the government to reestablish permanent cover. This time, more effort was given to match the seeded species to the soil, climate and surrounding vegetation. A growing knowledge of soil-plant relationships, use compatibility and plant management was demonstrated. When considering how ecologically sound CRP is being implemented, these three are key evaluation criteria.

However, history continues to repeat itself since man is slow to learn and quick to forget. The late 1970's and early 1980's saw the start of round 3, the plowout of the fragile Great Plains sod. Again, to try to produce crops that do not maintain adequate residue on the surface to keep the soil from eroding far in excess of its restorative capacity. The catalysts this time were distorted economic signals and shortsighted agricultural programs which fueled speculation and inflated prices for cropland. Income was guaranteed for cropping soils where crop failure and cost of production prevented profits otherwise.

So, for the third time in 50 years, the government is again involved in the revegetation of millions of acres unsuited for cropping.

Discussion

So what have we learned about the Great Plains ecosystem and how are we responding this time? How are we planning the vegetation planted to the soil, to expected future use, to the surrounding plant communities.

Let me suggest that we are improving. The figures that follow indicate we are doing somewhat better in selecting the species that fit the situation. In the acres with more fragile soil-plant relationships and where soil erosion is highest, such as New Mexico, Texas, and Colorado, more native species are being seeded. Wyoming and the other Northern Great Plains states appear to be an exception, however.

Let's take a detailed look at the changing land use picture. To date, 69,768 bids have been accepted in the Great Plains states (ASCS data). The number could increase to approximately 137,000 if a full 45 million-acre CRP is carried out, nationally. This provides an indication of the number of farms and ranches in the Plains that will be involved. Forty-two Great Plains counties have reached the 25% cropland conversion limitations (ASCS data).

Land use prior to the CRP is shown in table 1. Sixty-nine percent (385 million acres) of the private land was in a permanent cover of range, pasture, and trees. Thirty-one percent or 171 million acres was in cropland. Permanent cover varied from 40% in Kansas to 95% in New Mexico.

Table 2 shows the acres of highly erodible land in the Great Plains states that are eligible for CRP. The acreage varies from a low of 872,000 acres in New Mexico to a high of 13.9 million acres in Texas. The table also shows the percentage each state contains on a Great Plains and national basis. The main point is that 48% (49.1 million acres) of the eligible acreage is in the 10 Great Plains states. If the sign-up rate corresponded to the acreage, 21.8 million acres of participation would be expected.

However, table 3 indicates that after the fifth sign-up the Great Plains has provided 56% of the accepted acres. At that rate, if the full 45 million-acre goal of the program is achieved, a total of 25.2 million acres will be taken out of highly erodible cropland in these 10 states. Thus, almost 15% of the 171 million acres of cropland in the Plains will be taken out of crop production.

Table 4 indicates that, through the first four sign-ups, 95% of the acreage will be in permanent herbaceous cover. Permanent herbaceous cover in this case includes tame species (CP-1), native species (CP-2), and those acres already in grass (CP-10). I have shown, but will not include in the discussions, CP-3 and -11, trees; CP-4 wildlife habitat; and CP-5, field windbreaks. However, it should be noted that the wildlife habitat average is planted to herbaceous vegetation primarily, but may have woody species included to enhance food and cover value.

Table 5 provides a summary of the cover selection through the fourth sign-up for each state. Program rules were designed to allow flexibility at the local level for selecting the species that fit the situation and fulfill CRP objectives. It's obvious that the states are taking advantage of the flexibility when you study the percentage range in native and tame selections in each state.

The projections in table 6 shows the acreage of each cover type that is expected if the national CRP goal of 45 million acres is achieved. Pasture and range acreage will increase to approximately 24 million acres. This projection assumes that the cover selection pattern displayed during the first four sign-ups will remain constant.

In table 7, the projected increase in acreage of range and pasture is compared to the land use prior to CRP. The acreage of "already in grass" (CP-10) was distributed among range and pasture in the proportion CP-1 is to CP-2 (43% and 57%). The conversion will increase range by 4% and pasture by 27%. Another 1.2 million acres of cover will be planted specifically for wildlife habitat, also.

Effects

The changes outlined above will have a strong stabilizing effect on the environment of the Great Plains by initiating a regeneration of damaged soils and improvement of polluted water. To a more limited degree the change will enhance groundwater recharge and overall water yield--both critical elements of survival in the Plains. Also, the almost exclusive use of these acres by wildlife for the 10-year life of CRP contracts and

Table 1.--Pre-CRP land use (millions of acres) in 10 Great Plains states, as reported by USDA-SCS (1987) (1982 NRI).

State	Pasture	Range	Forest	Crop	Total
CO	1.3	24.2	4.0	10.6	40.1
KS	2.2	16.9	0.6	29.1	48.8
MT	3.0	37.8	5.2	17.2	63.2
NE	2.1	23.1	0.7	20.3	46.2
NM	0.2	41.0	4.7	2.4	48.3
ND	1.3	10.9	0.4	27.0	39.6
OK	7.1	15.1	6.5	11.6	40.3
SD	2.7	22.8	0.6	16.9	43.0
TX1	7.0	95.4	9.3	33.3	155.0
WY	0.7	26.9	1.0	2.6	31.2
Great Plains					
Total	37.63	14.13	3.0	171.0	555.7
Percent	6.8	56.5	5.9	30.8	100.0

Table 2.--Eligible CRP acres in 10 Great Plains states (unpublished SCS data).

State	Land area	Eligible land	
	(million acres)	Great Plains	50 States
CO	5.47	11.1	5.4
KS	7.03	14.3	6.9
MT	8.60	17.5	8.5
NE	5.03	10.3	5.0
NM	0.88	1.8	0.9
ND	2.79	5.7	2.7
OK	2.95	6.0	2.9
SD	2.04	4.1	2.0
TX	13.93	28.4	13.7
WY	0.38	0.8	0.4
Great Plains			
Total	49.1	100.0	48.4
U.S. Total	101.5	---	100.0

Table 3.--CRP acres accepted sign-up period 1 through 5. (Unpublished SCS data).

State	Accepted acres	Percent of eligible acres
CO	1,583,722	29.0
KS	1,979,917	28.2
MT	1,762,230	20.5
NE	949,358	18.9
NM	455,390	52.2
ND	1,448,885	52.0
OK	870,667	29.5
SD	846,764	41.5
TX	2,782,531	20.0
WY	215,721	56.2
Great Plains		
Total	12,895,185	26.3
U.S. Total	22,995,997	56.0

(Note: 64% of the fifth sign-up was in the Great Plains.)

Table 4.--Type of cover elected in sign-up periods 1 through 4 (unpublished SCS data).

Cover	Acres	Percent
CP-1 Tame Species	3,822,549	40.3
CP-2 Native Species	5,086,880	53.6
CP-10 Already in Grass	118,071	1.2
Subtotal	9,027,500	95.1%
CP-3 Trees	9,945	0.1
CP-11 Already in Trees	3,583	
CP-4 Wildlife Habitat	47,159	4.7
CP-5 Field Windbreaks	1,952	
Miscellaneous	870	
Total	9,491,009	99.9%

Table 5.--State CRP area (in thousands of acres) by cover type. (Unpublished SCS data).

State		Introduced grass CP-1	Native grass CP-2	Aready grass CP-10	Trees CP3&11	Wildlife Habitat CP4	Wind-breaks CP-5	Total
CO	Ac.	297.4	1,051.9	4.5	.6	67.7	.4	1,442.6
	%	20.9	73.9	.3	T	4.8	T	15.0
KS	Ac.	88.6	1,288.2	6.9	.8	6.4	T	1,391.0
	%	6.4	92.6	.5	T	.5	-	14.7
MT	Ac.	922.9	183.7	16.2	1.2	21.7	.5	1,146.1
	%	80.5	16.0	1.4	.1	2.0	-	12.1
NE	Ac.	325.0	329.4	11.6	1.2	133.6	.6	801.5
	%	40.6	41.1	1.5	.1	16.7	_	8.4
NM	Ac.	22.5	415.3	2.5	0	0	T	404.4
	%	5.1	94.3	.6	-	-	-	4.6
ND	Ac.	599.6	7.2	22.5	.4	83.1	.2	713.1
	%	84.1	1.0	3.2	T	11.6	-	7.5
OK	Ac.	321.9	375.0	10.9	T	.9	T	708.7
	%	45.4	52.9	1.5	T	.1	-	7.5
SD	Ac.	310.8	77.0	27.0	.5	40.2	.1	455.6
	%	68.2	16.9	5.9	.1	8.8	-	4.8
TX	Ac.	801.5	1,358.7	13.6	8.7	69.9	T	2,252.5
	%	35.6	60.3	.6	.4	3.1	-	23.7
WY	Ac.	132.3	.4	2.2	T	23.7	T	158.7
	%	83.4	.3	1.4	T	14.9	-	1.7
Great Plains								
Total	Ac.	3,822.5	5,086.9	118.1	13.5	447.2	-	9,490.1
	%	40.3	53.6	1.2	.1	4.7	-	100%

hopefully beyond may be extremely beneficial to wildlife populations.

Concerns related to the management and maintenance of the seedings during the life of the contract should be noted. If the vegetation is properly managed, the end result will be a viable, productive stand providing the owner many more options for use; e.g., wildlife habitat, seed production, hay, forage, hunting and other recreation, watershed protection, water yield, etc. If not properly established and managed while under contract, the stand may deteriorate to where re-establishment is needed or the area becomes a source of undesirable weeds in the community.

Several problems have arisen. Most are directly related to the sudden surge in the demand for seed and the resulting seed shortage that is being experienced. The use of short-lived perennials has increased the problem. This creates a possibility that stands will deteriorate before their contracts expires and erosion control will, therefore, not be adequate. Incompatible mixtures are being seeded. Increased seeding rates to offset use of poor quality seed has increased the total amount of weed seeds planted. Foreign seed of questionable origin and adaptation is being used. Seed testing results are questionable in some cases. Mislabeling of varieties is appearing. Seeding specifications are being altered to "ease the problem." All of these can have long range negative repercussions.

Certain other deductions can be made. First, the acres planted to trees are more likely to remain out of crop production when contracts expire. Next most permanent is the 14.9 million acres planted to wildlife cover.

Table 6.--Projected Great Plains average by cover type (assumes CRP goal of 45 million acres).

Cover	Percent to date	Projected acres *(millions)*
CP-1 Tame Species	40.3	10.2
CP-2 Native Series	53.6	13.5
CP-10 Already Grass	1.2	0.3
Subtotal	95.1	24.0
CP-3/11 Trees & In Trees	0.0	(0.3)
CP-4 Wildlife Habitat	4.7	1.2
Great Plains total	99.9	25.2

Table 7.--Projected land use change by CRP.

Use	1982 acreage	Projected CRP change	
	(Million)	*(Million acres)*	*(Percent)*
Cropland	171.0	-25.2	-14.7
Pasture	37.6	+10.3	+27.4
Range	314.1	+13.7	+4.4
Trees	33.0	+.1	+.3

Table 8.--Project reduction in annual erosion on the Great Plains through first four sign-up periods (9.5 million acres) and for projected maximum (25.2 million acres). (Unpublished SCS data).

State	Reduction	
	(Tons per acre)	*(Million tons)*
CO	26.3	37.4
KS	18.5	25.7
MT	14.3	16.4
NE	25.1	20.1
NM	41.4	18.2
ND	15.4	11.0
OK	24.6	17.4
SD	13.3	6.1
TX	38.3	86.3
WY	12.3	2.0
Great Plains Total	25.35	240.6
Sign-up 1-4 maximum	25.35	638.8

Native species may tend to have more permanency than the 10.3 million acres planted to tame species due to the higher investment and long-lived characteristic of native species.

Second, these acres can become a significant forage resource. Assuming an average of 2 animal unit months (AUM's) per acre production on the pasture added and 0.4 AUM's per acre for the range added, there is a usable potential forage production of 25 million AUM's. This is adequate forage for 2.5 million cows for 10 months. At 1.25 tons of hay per acre the 10.3 million acres seeded to pasture species could produce about 13 million tons of hay after the contracts expire.

Another alternative should not be overlooked. The entire acreage planted to tame and native species has a seed harvest potential; a good reason why it is in our best interest to seed desirable varieties. If we do, CRP presents an ideal opportunity to rapidly increase the supply of improved varieties.

Another major impact of a 45 million acre CRP will be an annual reduction in soil loss of 639 million tons (table 8). This reduction is 85% of the annual total soil loss reduction expected for the entire nation when the program was conceived. The Great Plains reduction to date is 66% of the national reduction. Compare this to the fact that only 56% of the acres accepted are in the Great Plains. Reduced erosion means less sediment, pesticide, and plant nutrient movement into waterways, thus improving the quality of water for human consumption and use, agricultural production, fish habitat and recreation.

Conclusion

In conclusion, if the CRP achieves its 45 million acre national goal, 25.2 million acres of highly erodible cropland in the Great

Plains will be re-established in permanent vegetative and woody cover. Approximately 54% of the acres will be planted to native species. This closely parallels the 56% of the land currently in range. Annual soil loss reduction averaging over 25 tons per acre will improve the quality of water and life in the Great Plains. Acknowledging that CRP appears to be achieving its erosion reduction objectives in the Plains, the ultimate challenge will continue--can we keep from repeating the mistake of tilling the fragile soils of the Great Plains for the fourth time? Hopefully, this symposium will be a first step in preventing this cycle which appears to have become a U.S. tradition.

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The Economic Impact of Farm Policy Changes on Rural Communities: Conservation Provisions--A Case in Point

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Abstract.--The Conservation Reserve Program (CRP) highlights the fact most farm policy programs impact not only producers but also rural communities and counties where the producers are located. This is usually the case when agriculturally dependent areas are involved. The Great Plains region, including the Oklahoma Panhandle, falls in this agriculture-dependent category. This paper examines the linkages between agriculture policy and rural communities with a brief review of the literature. The CRP is briefly summarized. Data and statistics are presented for Oklahoma including a summary of observations gained from visits to highly impacted areas. Finally, an example county is analyzed in terms of the possible economic and social impacts of the CRP on the local economy.

Agricultural Policy and Rural Communities

Farm Policy and Farm Structure

Much discussion has centered on the question of farm policy impacts on farm structure. The number and sizes of farms constitutes an important topic when examining economic impacts of farm policy changes. Knutson et al. (1986) noted there are several factors affecting farm structure including technological change, economics of size, tax policies, and farm policies. Tweeten (1983) discussed several areas of public policy affecting agriculture including monetary-fiscal policy, export policy, tax laws, resource policies, as well as commodity programs for agriculture. In addition to problems caused by nature, politics and business cycles, Tweeten noted the farming industry faces cash-flow problems induced by inflation and interest rates. Regardless of the debate concerning the significant factors affecting farm structure, it is apparent farm structure is important in agriculture-dependent areas just as the future of the auto industry is important for areas deriving large levels of employment from automobile production.

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Farm Structure and Rural Communities

Tweeten and Brinkman (1976) pointed to several elements influencing community economic growth including attitudes, natural resources and existing institutions such as schools, banks, and government. Growth occurs through savings and investment depending upon the rate of resource use as well as efficiency of resource use within communities. Agricultural communities such as those in the Great Plains area of the United States have relied on natural resources in the form of agricultural production to produce growth. For those communities the existing and future structure of agriculture is important. Even among the agriculture dependent areas defined by Bender et al. (1985), the type of commodity produced varies. Thus, input purchase patterns and linkages to the community will vary. Michaels and Marousek (1978) examined the impact of farm size alternatives on rural communities in Idaho. Replacing small farms with larger farms resulted in greater regional income while increasing the number of small farms lead to greater regional employment. Other factors which were noted to be important for rural development in small towns included trading patterns and opportunities for nonagricultural development.

In a study of rural population growth, Albrecht (1986) reported counties dependent on agriculture are likely to experience population declines in the future. He noted that the rural population turnaround of the 1970s was not shared by all rural

communities. Doeksen (1987) analyzed the agricultural crisis as it affects rural communities through a case study. A lost of 20% of the farmers in a rural community was shown to impact not only employment and population, but also community service requirements and local government revenue.

Communities and Farm Well-Being

Ladewig and Albrecht (1983) reported on the changing agricultural industry in Texas and the nation. They noted the importance of off-farm employment for farm families. Due to the instability of farm income, severe cash flow difficulties, and low farm prices, many farm families depend on off-farm income as a means of continuing farming at all. Powers and Hobbs (1985) emphasized that support for rural economic development is complementary to the needs of farmers, not competitive. Even though scarce resources are available for assistance, providing help for the community in general will likely help the farm families who are trying to survive. Research aimed at understanding the linkages between farms and the rural community will strengthen this agreement and it will be useful to quantify the types of linkages by types of communities and farms.

Food Security Act of 1985

While commodity programs and spending have overshadowed discussions related to the Food Security Act (FSA) of 1985, many producers have only recently started to become aware of other significant aspects of the legislation. The conservation provisions are among those that will have potentially major impacts on agriculture and the economy of Oklahoma and other states.

The conservation provisions are intended to accomplish two lofty, yet very basic, goals. The first is a significant reduction in soil erosion. Additionally, it is hoped that such a major removal of cropland from production will significantly reduce excess capacity for commodity production. However, Congress hopes to achieve these goals without adversely impacting farm income, rural economies and the federal budget. The likely effects of these provisions will be far-reaching, including the following:

1. A decline in cropland erosion;
2. an uncertain impact on commodity production and price levels;
3. possible increase in "wildcat" farming outside government programs, thus leading to uncertain erosion effects on such land;
4. acceleration of the structural trend toward larger operations;
5. increasing stress on the economic viability of some rural communities;
6. increasing growth of some communities as trade centers;
7. possible political pressure to change policy to lessen adverse regional impacts; and
8. a decline in off-farm impacts of erosion, including an increase in water quality.

A diverse group of interested parties took part in discussions over a land conservation component in the 1985 Farm Bill during the two years prior to enactment. These included conservationists, small family farm producers, large scale operators, agribusiness and agriculture credit representatives, and agricultural organization leadership from all spectrums. At least three points were emphasized:

1. soil erosion had grown to the point that future productivity of American agriculture was severely threatened;
2. the old Soil Bank approach of the 1950's, along with other attempts, had proved inadequate; and
3. while the cost of doing nothing about erosion might prove devastating in the long run, the immediate cost of a large scale conservation program would not set well in the budget-cutting environment of Washington.

The result of such concerns was a conservation title that contained these programs: the Conservation Reserve Program, Sodbuster, Swampbuster, and Conservation Compliance. The Agricultural Stabilization and Conservation Service (ASCS) has just closed the fifth bid period for CRP. Data available from the first five periods show USDA has now approved just under 23 million ac. for CRP contracts nationwide, and over 890,000 ac. in Oklahoma.

Background

"Highly erodible land" has become the target of increasing concern during recent years. While the term is technically defined in the Bill and implementing orders, the idea is straightforward. Such land converted to agricultural production, often intensive, has pushed the average annual rate of erosion to levels that range from 10 tons/ac. to 30 tons/ac. This is contrasted with a generally accepted annual rate for all cropland of about 5 tons/ac.

Ironically, many of the federal farm programs designed to help farmers have also created the incentive to convert marginal land with high erosion potential into intensive cropland, thus worsening the problem. While good intentions and opportunity do not always coincide, the current conditions of high stocks provided the opportunity that conservation-minded policymakers were needing.

As noted in Congressional analysis of the problem, taxpayers were paying both for the incentive to worsen the problem and for

the consequences of erosion. The off-farm cost of dealing with sedimentation has been estimated to be $2 billion to $6 billion per year.

Efforts of the Soil Conservation Service (SCS) and ASCS, while noteworthy, have not kept pace with offsetting incentives to mine the soil for short-term gains. The Soil Bank did not specifically target highly erodible land. Instead, it became more of a production restriction program. Requirements for conservation cover on set-aside acreage enrolled in commodity support programs has helped somewhat. Again, however, highly erodible land has not been targeted in the past.

The Natural Resources Inventory of 1982 provided a focus for the problem. This showed about 50% of the sheet and rill erosion was occurring on only 10% of U.S. cropland. The Soil and Water Resources Conservation Act of 1977 provided for pilot projects that pointed to possible solutions. Land conversion projects were conducted in Pike County, Alabama, Stanley County, South Dakota, and Willow Creek, Idaho. More than half of the project land had been eroding at more than four times the tolerable rate. By paying landowners to stop cropping and covert back to grass or trees, preliminary results indicated success. And, more significantly from a budget standpoint, contracted acreage would save the government money on commodity price support program expenditures.

The 1985 Farm Bill Solution

The concerns over conservation issues for agricultural land were resolved in the 1985 FSA with a title that specifically targets highly erodible land to be taken out of crop production, kept out of crop production, or farmed in new conserving ways. The CRP affects highly erodible cropland planted at least 2 years between 1981 and 1985. Conservation compliance affects highly erodible land planted at least one year 1981-1985 and being farmed in 1990. The Sodbuster provision impacts anyone who farms highly erodible lands that were not planted before December 23, 1985, and do not have an approved conservation plan implemented for that crop year. The Swampbuster provision provides ineligibility rules for those who plant on wetlands converted after the date of enactment. Because implementing rules for the conservation provisions are subject to change, the producer will want to verify them with SCS/ASCS prior to making decisions.

Conservation Reserve Program (CRP)

The new CRP requires that 40-45 million acres be put under contract for long-term set-aside of 10-15 years. Implementation has been for 10-year contracts. The Bill established a minimum annual acreage placement schedule as follows: 1986 - 5 million acres; 1987 - 10 million acres; 1988 - 10 million acres; 1989 - 10 million acres; 1990 - 5 million acres.

Normally, no more than 25% of the cropland in any county can be placed under contract, although there are special procedures to request a one-time exception providing it does not "adversely impact" the economy of the region. The annual rental payment may not exceed $50,000. Generic payment in kind certificates have been designated as the form of payment in the implementation by the Secretary. The Bill allowed USDA to place under contract the entire 45 million acres as soon as possible. If payments are likely to be significantly lower in the next year, the Secretary may reduce the annual minimums for 1986-1989 up to 25%.

The contract producer must agree to the following provisions:

1. to implement the conservation plan of operation provided by ASCS;
2. to place the acreage in the CRP for 10 years;
3. to not use the land for agricultural purposes unless permitted;
4. to establish approved permanent vegetative cover (trees, native grasses and legumes, introduced grasses and legumes, wildlife habitat or field windbreaks);
5. to not conduct harvesting or grazing or make commercial use of forage; and
6. to not plant trees, unless permitted.

The SCS has estimated that 104 million acres were eligible across the nation, with 2.2 million eligible acres in Oklahoma. For the purposes of the first two bid periods (March and May, 1986), the technical criteria were simplified to all class VI and above cropland and any class II through V cropland eroding at least three times the normal soil loss tolerance. State technicians estimated that about 1.7 million ac. of Oklahoma cropland qualified.

For the third bid period in August, 1986, the CRP definition of highly erodible land was expanded to include class II through V that was eroding at two times normal and had visibly gully erosion. The fourth signup in February 1986 contained an even broader definition that essentially brought CRP eligible land into conformity with Conservation Compliance and Sodbuster. The definition is a technical index, the erodibility index (EI), based on the inherent erosion potential of the land. It considers length and steepness of slope, climate and soil characteristics. Land that has an EI greater than or equal to eight is considered eligible. The SCS estimates some 4.7 million ac. meet this criteria in Oklahoma.

Impacts of the Conservation Reserve Program

As noted in the earlier literature review, an agricultural policy such as the CRP impacts a local economy by having some effect on one of the basic industries (agriculture) in most economies. In the relationship between a basic industry, such as agriculture, and the community economic system, households are provided in-

come and, in turn, provide labor to the industry. The service sector of the economy (mainstream business such as drugstores, hardware stores, etc.) provides goods and services to the households. The service sector may also provide inputs to the basic industry (for example, agricultural inputs). The basic industry in the local economy would be agriculture. The CRP impacts that industry. Households, particularly farm families, are impacted in at least two ways. A farm income impact results from the rental payments of CRP. The flow of this income depends on the consumption and saving patterns of the farm families. An additional income impact is the cost of compliance for CRP. The service sector is impacted through changes in production patterns and input demand. Also, farm households may spend CRP rental payments in the local economy. The net impact on the local economy will depend upon the magnitude and direction of responses to changes in the basic industry.

There are several critical areas where impacts may occur when there is a change in the base of a local economy. Listed in table 1 are key areas to consider in impact assessment. The first area considered is economic impacts. Depending upon the direction of the economic change, jobs and income can be added or lost to the local economy. Overall business activity is also impacted as indirect "multiplier" effects are felt in the local economy. Demographic or population impacts can also result from a change on the economic base. Population change may occur--growth if additional jobs are available and decline if enough jobs are lost. Demographic characteristics of the local population are important to economic change. Some key characteristics include age, sex, and labor force participation. Community services will also be impacted if the population base changes. What will be the level of services and facilities required and will there be a tax base to support the required level of services? Finally, there will be social impacts in the local community as well.

Table 1.--Key impact assessment areas.

1. Economic
    - Employment - jobs
    - Income
    - Business activity
    - Direct and indirect impacts
2. Demographic
    - Population change
    - Details will vary by age-sex
    - Labor force participation
3. Community Services
    - Will depend on population impacts
    - Does excess capacity exist
    - Schools
    - Water, Sewer, solid waste, health care
4. Fiscal
    - Tax base - revenue
    - Provision of services
5. Social

Table 2.--Employment data by sector for Cimarron Co., Oklahoma and the United States, 1984.

	Cimarron County[1]	% of total	U.S.[1] *(thousands)*	% of total	Location quotient[2]
Proprietors					
Farm	604		2,637.0		
Nonfarm	290		14,753.9		
Industry					
Farm	811	.421	3,797.0	.032	13.16
Ag. Serv., Forestry Fish, other	47	.024	1,130.7	.010	2.40
Mining	51	.026	1,283.9	.011	2.36
Construction	33	.017	5,830.0	.049	0.35
Manufacturing	11	.006	19,774.9	.167	0.04
Transportation and Public Utilities	88	.046	5,681.1	.048	0.96
Wholesale Trade	59	.031	6,011.0	.051	0.61
Retail Trade	191	.099	19,237.0	.162	0.61
Finance, Insurance, Real Estate	55	.029	8,377.0	.070	0.41
Services	191	.099	28,424.3	.240	0.41
Government	388	.202	18,944.0	.160	1.26
Total	1,925	1.000	118,491.9	1.000	

[1]*Source: U.S. Department of Commerce, Regional Information System, Bureau of Economic Analysis.*

[2]*County percent of total divided by U.S. percent of total.*

The stress level in many rural communities resulting from the current agricultural crisis is an example of potential social impacts. The critical impact areas listed in table 1 can all be considered when analyzing the potential impacts of CRP. In many counties, the level of participation in CRP is so low, relative to overall agricultural activity, that the impacts will be minimal.

For the purposes of discussion in this paper, an Oklahoma county is used as a discussion focal point. Cimarron County is located in the Oklahoma panhandle at the Western tip. The county is primarily agricultural with $81.8 million in cash receipts from farm marketings in 1984. This includes $63.4 million in livestock and products and $18.4 million in crops. Cimarron county had a 1980 population of 3,648, while the county seat, Boise City, had a population of 1,761. Employment data for Cimarron county is listed and compared to U.S. employment in table 2. Of the 1,925 jobs listed for the county in 1984, 811 were in the farm industry with an additional 47 in agricultural services. A location quotient (LQ) is calculated by comparing county employment with United States employment. For each sector, the percent of total employment for the county is divided by the percent of total employment in the U.S. The resulting LQ provides evidence of the level of export activity. A LQ greater than one indicates the county is a net exporter in that sector while

a LQ less than one indicates the county is a net importer. As can be seen, the farm sector for Cimarron county has an extremely large LQ showing the importance of this sector to the local economy.

The analysis of Cimarron county employment data is continued in table 3 by calculating the level of export employment using the location quotients. For a detailed explanation of the technique used see Hustedde, et al. (1984). Of the 885 export related jobs in the county, 749 are in the farm sector. The export base multiplier is estimated to be 2.18, meaning for each additional export related job, a total of 2.18 new jobs are created.

Cimarron county was chosen as an example because of the large acreages in the county qualifying for CRP. After the first four bid periods, 148,800 ac. were approved in the county. This represents about 32% of the total farmland in the county. Bids during the first period ranged from $5 to $40 per acre but came in around $40 during the second period.

At $40 per acre, this represents about $5.9 million injected into the local economy each year for 10 years. The secondary impacts of this income will depend upon consumption and savings patterns of the farm families receiving the money. At one extreme, rental payments and establishment cost-share funds will equal the decrease in production income. If recipient producers use this income on farm inputs following similar spending patterns as before their contract, there will be essentially no change in income flows and employment in the community. If, however, the farm family uses the CRP income for retirement of existing debt and/or non-farm enterprise consumption or saving, there will follow a redistribution of benefits away from local agribusiness and to other sectors in the local economy or a nearby trade center. In fact, existing or potential "growth pole" communities may be significant winners as a result.

Alternatively, rental payments could be greater than the decrease in production income. It is unlikely that rental payments will be less than production income, because producers are assumed to seek the more profitable alternative. If they underestimate future market conditions, they will likely buy their way out of the contract. Where rental payments are greater than the decrease in production income (and field work seems to support this likelihood), changes in consumption and savings patterns become even more critical. A result of this scenario could be that all sectors in the local community are better off, as well as nearby trade centers gaining business.

Table 3.--Estimate of export employment for Cimarron Co., Oklahoma.

	Location quotient (LQ)	% of employment serving non-local needs[1]	Employment Total	Employment Export
Farm	13.16	92	811	749
Ag. Serv., Forestry, Fish, other	2.40	58	47	27
Mining	2.36	58	51	30
Government	1.26	21	388	80
Other			628	
Total			1,925	885

[1]*Calculated as* $(1 - \frac{1}{LQ}) \times 100\%$

Employment Multiplier $\frac{1925}{885} = 2.18$

Summary

The CRP is an example of a farm policy which impacts not only agriculture but also the local economy of rural areas. In agricultural dependent counties where high percentages of CRP approved acreage exists, the impacts will be greatest. The income injected into the local economy through rental payments will benefit the local economy but the local impacts will be tempered by spending patterns and local sales leakages. Decreases in input purchases will be felt by the local farm input dealers, while increases in general consumer goods and services and savings will boost other sectors of the local economy and/or enhance the economy of a nearby trade center.

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Implications of Land Conversions and Management for the Future

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Abstract.--The Conservation Reserve Program (CRP) is a massive effort by Congress to check soil erosion on highly erodible cropland. This is to be accomplished by establishment and long-term maintenance of perennial vegetation on this land. The long-term success of the CRP depends on three critical constraints: (1) long-term financial attractiveness to cooperators; (2) social consistency with cooperator needs and desires; and (3) ecological compatibility with environment to be reseeded. Recommendations to augment program success are to phase in the program over a longer time period and provide: (1) in-depth workshops on seeding technology and equipment; (2) renewed emphasis on planning to meet the needs of clientele; (3) quantitative monitoring programs; and (4) forage management programs for stand maintenance.

A goal of the Conservation Reserve Program (CRP) is converting 45 million acres of highly erodible cropland back to perennial cover and maintaining this cover as a method of reducing erosion. An unstated goal is to maintain perennial cover beyond the duration of the CRP. In the first year the CRP registered 8.9 million acres, including over a million acres of cropland in Colorado (Bartlett and Trock 1987). Certainly, the stated and unstated goals are appropriate for the program. The targeted lands have accelerated erosion which produces great loss of soil and subsequent loss of productivity. The question is: "How can we accomplish these goals given land that has limited potential and that has lost productivity because of erosion and soil loss?"

A look at past experience in reseeding Great Plains areas indicates it has been treated with a broad-brush approach. For example, millions of acres of crested wheatgrass *(Agropyron cristantum)* have been planted in the Northern Plains of Montana, North Dakota, Alberta, Saskatchewan, and other states (Lorenz 1986). Smooth brome *(Bromus inermis)* was planted on thousands of acres in the Midwest, including Nebraska, parts of South Dakota, and Kansas. Old world bluestems or KR bluestem (*Andropogon* spp.) were planted in the Southern Plains (McIlvain and Shoop 1960). In many cases, however, the broad-brush approach did not fit all of the needs; and many of these lands have been replowed.

Seedings that remain fail to meet a particular need, resulting in reduced productivity of livestock or wildlife. Sod-bound smooth brome remains on hundreds of acres in South Dakota. These reseeded areas provide a perennial cover but provide poor to inadequate wildlife cover and very low production. KR bluestem in the Southern Plains is only fair in palatability and is low in quality during much of the year. Crested wheatgrass, planted on millions of acres in the Northern Plains, is low in palatability for mid- to late-season grazing, causing large areas to be less than optimum for grazing except during early spring. In all of these cases, these grasses did fill the need to provide perennial cover. Because of their shortfalls in the broad-brush approach to reseeding, however, much of this rangeland either failed to provide need of the producer and in some cases has been converted back to cropland because of this failure. Alternative species combinations with a more flexible approach would have increased the land's value to the cooperator and, perhaps, the longevity for these stands (Sims 1985).

Central Theme

The theme for this paper is: "What do we have to do to accomplish our long-term goals?" First and foremost, the cooperating producer is the person who implements and maintains the project and it is he who will spell success or failure for the program. A retrospective look at the basics of planning may give us an enlightened viewpoint: evaluate the goals and the resources available; build a set of alternative plans; critically evaluate the best approach with respect to goals; implement, monitor, evaluate, and alter a plan according to new information.

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We must do the best possible job of planning the reestablishment of perennial species in all the rangeland areas. Unfortunately, the CRP has become a crash program resulting, at times, in inadequate planning; accepting poor or inappropriate substitutes for seed sources, improper technique, equipment, and/or timing of the reseeding. The key considerations for success in this program over the long term are:

1. Alternatives must be financially attractive to the cooperator over the long term;
2. Alternatives must be consistent with social concepts of cooperators; and
3. Alternatives must be environmentally compatible with the area, climate, and soils for which the seeding is to be adapted.

Financial Attractiveness

Will net return to the operation be increased as a result of the practices that are being applied? This becomes especially relevant when the government no longer provides dollar incentives for continuing the program. At that time the practices must provide a financial incentive for the cooperator to maintain a perennial cover on that land. Frequently, failure to meet this criterion has resulted in land being plowed after rental payments terminate. Therefore, we have a cyclical phenomenon of plowing, reestablishing perennial cover, plowing, and reestablishing perennial cover.

The alternative chosen must be compatible with the farmer's current operation or with future plans in the operation. Failure to meet this criterion will cause the cooperator to define the alternative as financially unreasonable for him to pursue. The following are some constraints for evaluating the financial compatibility of alternatives to an operation (Vallentine 1971):

1. What type of livestock can or will use the forage crop subsequent to the time of the reestablishment program?
2. Will the seeding provide a needed special use, such as lambing or calving pasture, breeding pasture, pasture for fattening for yearlings, or winter range for livestock and/or wildlife?
3. Will the seeding reduce the amount of hay or supplements that are needed for that operation?
4. Is additional seasonal grazing needed to balance a year-long forage supply? If so, at what season of the year is that most important?
5. Will the seeding benefit other areas by allowing stocking rates to be reduced, season of grazing altered, turn-out dates delayed, or a special grazing system initiated?
6. Are special considerations such as erosion control, fire breaks, and wildlife habitat important?
7. Will new fences be required to protect the seeding or to exclude grazing to allow management of the seeding?

A consideration that must be included is whether stock water is available to the seeding or if it can be developed for a reasonable cost. How should the forage crop be managed after a stand is established? How long will a seeding last, and will the seeding have to be redone? Cash costs or out-of-pocket costs become critical considerations in the planning of these reseeding alternatives. What will the cost of maintenance be? This can be particularly important where brush or weed invasion becomes a problem because of the alternative chosen, the land type, or the particular weather following the time of seeding.

Evaluating all of the applicable considerations is the key to producing a financially attractive alternative for a cooperator. One must consider all the costs, whether they are direct costs (e.g., the cost of seed, seed-bed preparation, and weed control) or indirect costs (e.g., risk, changes in land value, tax base, etc.), balanced against the benefits or revenues that will be returned from the reseeding operation (Kerr and Dooley 1982). Other benefits, although not directly attributable to revenue, may include reduction of erosion and maintenance of long-term productivity of the land base. Increased wildlife value, whether that happens to be a commercially harvestable species or small game and birds, can be an important benefit to some cooperators.

Socially Consistent

Social consistency is a tough area to identify quantitatively. It will have a large effect, however, on whether land will continue in perennial cover. Successful programs are consistent with views and needs of cooperators (Greenwood 1986). Several key points should be considered in evaluating and planning a program. Most importantly, the activity must be compatible with the views of the cooperator. A program which the cooperator is not comfortable with or disagrees with is inevitably a failure because he or she has no commitment to the program's success. Even economic or political pressure is not sufficient for a non-committed cooperator to have a vested interest in the program. Programs must, therefore, be developed which do not have broad base formulas but are informed and custom-designed to meet the joint views of the cooperator and technical agency. Frequently, the agency must be able to sell a program to accomplish the need and pursue the job with flexibility to make the program a success. Field level decision making is the most effective way to accomplish any activity.

A program must be consistent with management interest and capability of the producer in the short- and long-term. The best technically planned and implemented seeding program will fail in the long term if the cooperating producer cannot, or will not, provide the management required to maintain that seeding.

Environmentally Compatible

The third major consideration is that any plan must be environmentally compatible. Species adaption to the need, land, and climate is a primary concern. A species or combination of species must be capable of good productivity over an extended period of time. Inherent to that is the necessity of hardiness of the species planted. The species must be drought tolerant, cold tolerant, and capable of withstanding defoliation and competitive plant pressures. Other papers in this Proceedings address this subject.

Many species have recently become available for use in reestablishing perennial cover. Both native and introduced species can fit the needs in many areas of the Great Plains. Most seed sources of "native" seed are introduced plant material because of selection and breeding development involved in the plant materials process. It seems, then, that plant material should be selected according to its ability to fit the environment and need rather than because it is purportedly a native species. Grazing types of alfalfa fit into this category and have been under-used in this program as a forb.

Stand establishment and maintenance is important to the success of the program, environmentally and economically. The best technology of stand establishment, in many cases, is not well defined (McLean and Wikeen 1984, Great Plains Agricultural Council 1966). Therefore, specifications for seeding are subject to the experience of the field people and other technical advisors. The opportunity to show cause and effect relationships, as well as support for research in new technology, has largely been ignored. This is, again, an influence of a crash program. Mitchell and Evans discuss research needs in a paper of this Proceedings.

Risk of stand establishment is a function of technology, weather, and available plant materials. In many areas of the Great Plains, the risk of seeding failure is relatively high with good conditions and very high in less than optimal conditions (McGinnies et al. 1983, Great Plains Agricultural Council 1966). Studies done in Colorado on stand longevity for seeded species indicate that 50% failure rates of stand establishment and maintenance is common. Seeding conditions in eastern Colorado are severe, and risk is a large factor in cost and long-term use of reseeded land. Even seedings that showed good stand establishment in the early years dramatically lost stand vigor in subsequent years. This appeared to be caused by both climatic and management effects.

Erosion control is a consideration in environmental compatibility. Some stands establish and provide adequate to good erosion control very quickly. However, some approaches (i.e., repeated cultivations or slow established species) can provide less than adequate erosion control, especially in early years or during adverse weather conditions.

Weed management is part of the environmental compatibility constraints. Weed control before and after seeding is critical to the establishment of good stands of perennial species. Aggressive weeds can cause large reductions in seeded stands on CRP acres; hence, weed control should be included in incentive provisions.

Special considerations of watersheds are also part of the environmental compatibility. Watershed stability and effectiveness of maintaining watershed stability are critical to the intent of the CRP. Frequently, speed of establishment is critical to special watershed conditions so that gully erosion does not develop and adversely affect the watershed over a long period of time.

Recommendations

We have discussed the considerations which must be in place to achieve long-term stability of the CRP and what is required to allow producers to maintain these stands beyond the rental period. The question is, "where should we go from here?" The following is a set of recommendations which I consider to be critical to providing the appropriate alternatives or considerations to guarantee long-term success of the CRP.

The program should be phased in over a longer period of time. This would allow time for better planning, a more even work load, seed companies to better meet increasing demands, and staggering the times when lands come out of the program. Vallentine (1983) indicated that technology and technology transfer, particularly in relation to rangeland seeding, was inadequate in some cases. To alleviate that problem, I would suggest there be in-depth workshops on seeding, seeding equipment, and seeding techniques as a cooperative project with the Extension Service, seed companies, equipment dealers, contractors, and other interested people to provide the most current technology available. Additional applied research is needed to evaluate management practices for feeding as well.

The second recommendation is to reevaluate the planning process. I feel that planning is one of the keys to providing long-term success in this program. Plans must be consistent with cooperator needs, desires, and environmental compatibilities as outlined before implementation of the plan.

The third recommendation is a sound monitoring program of the CRP activities. In other words, bring technical cooperators into the field when the people are drilling; observe how they are applying the technology; evaluate what the subsequent effects are on success of the stands. There needs to be follow-up field checks to monitor a cause-and-effect relationship. Combined with that, however, there needs to be firm quantitative criteria for field evaluation. A data base of the combined observations needs to be developed, maintained, and used. Without monitoring there will be no real feedback of program success or quantitative evaluation of planning activities.

The last recommendation is that there be firm plans for forage management after the stand is established, including residue management. Residues of perennial species should be reduced. There should be some kind of flash grazing program every third year during the vegetative growth period. Burning is another alternative. Residue management will both increase the vigor of the plants and serve as a mechanism to control residue accumulation over the time period. Additionally, I think in many cases

forbs and perhaps grazable browse plants have been largely overlooked in the plans for forage management.

I would like to see a follow-up evaluation and, perhaps, interseeding of both forbs and shrubs that would facilitate long-term management and values of these stands. These will greatly enhance seasonal forage quality and give additional forage quality in extended grazing seasons. I believe these recommendations will greatly enhance the quality of the program and the probability of long-term success of the CRP.

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Improving Ranch/Farm Success Through Total Ranch Management Planning

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Abstract.--Ranching and farming success can be improved through use of a strategic planning process. Total Ranch Management planning utilizes goal achievement through selection of tactical alternatives and operational activities within ranch and farm resources. Planning identifies achievable activities and uses the plans to monitor current progress and make adjustments to optimize opportunities and reduce risk. Effective use of limited resources requires establishing priorities that solve problems and not treat symptoms. Landowner investments should be where the highest benefits can be achieved and most productive resources conserved to improve success in the future.

Ranching and farming today has changed from the 1970's, a period marked by land appreciation, operations expansion, and increasing dependence on technology. Many ranches and farms are no longer solvent. Those that are surviving have maintained debt obligations within cashflow realities of agricultural production. High overhead expenses have been a primary cause for financial troubles. However, the real cause may have been management's failure to use adequate recordkeeping, planning and analysis tools to properly select the right things to do within ranch and farm resource capabilities.

A systematic approach is needed by most ranchers and farmers to organize and analyze information to improve decisions. "Most [managers] have learned by bitter experience that intuition is unreliable, if not downright treacherous, if used as the only basis for decision" (Drucker 1974). The use of "expert" opinion, research findings, new technology, etc., must be justified by each manager for their unique situation. What works well for one operation may have adverse effects for a neighbor. Also, the technology may work but not be the most important use of limited resources for the individual ranch or farm.

The Total Ranch Management (TRM) approach utilizes a systematic planning process from top down (strategic) to daily operations that better define the problems, assumptions, performance standards, and selected alternatives for effective use of resources. "Strategic planning is the continuous process of making present...risk-taking decisions systematically and with the greatest knowledge of their futurity; organizing systematically the efforts needed to carry out these decisions; and measuring the results of these decisions against the expectations through organized, systematic feedback...Systematic planning is necessary precisely because we can not forecast" (Drucker 1974).

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Strategic Planning and CRP

To be successful, operational activities must achieve tactical objectives that when summed together accomplish the strategic goals of the ranch or farm. The strategic goals and available resources determine the appropriate tactical solutions (enterprises) within a given market environment.

Management is fully responsible for ranch or farm performance, success and failure. Forecasting is necessary but inaccurate, hence risk and uncertainty (hedging against loss) is of paramount importance. Protecting assets is equally as important as investing assets. "All goals lie in the future and thus require forecasting" (Duerr et al. 1971); however, a rancher/farmer must succeed today in order to benefit from the future.

The conservation of natural resources requires balancing demand and supply with adequate allocation for maintenance of the system. The rancher/farmer gives up some "potential present value" as an investment to produce future renewable resources. Financial crisis situations force managers to over-extend use of resources for todays survival. Often these decisions create new crises that increase in frequency and further erode resources.

Strategic planning to conserve resources must consider the total ranch/farm operation. The needs and goals of an individual are often in conflict with that of the population. The Conservation Reserve Program (CRP), Sodbuster and Swampbuster provisions must meet strategic goals of individuals and the nation if they are

to survive. "Good" management decisions must be rewarded and chances of success improved if conservation of resources are to be encouraged. A common strategic goal for the land manager and the nation must be recognized.

Just like the rancher/farmer, national investments must be made where resources can benefit most and provide the higher rate of return. In general, ranchers and farmers are encouraged to invest on the most fertile sites rather than on areas where few benefits can accrue.

Using a TRM planning approach, problems can be better identified and solutions selected rather than treating symptoms. "The most important element in effective decisionmaking is defining the problem" (Drucker 1974). Drucker further points out that it is important to decide whether a need for a decision exists.

The CRP provisions are needed to cure past abuses and "protect" certain fragile lands. However, maintenance of the Nation's productivity hinges on the most effective use of limited resources. Selecting the right things to do, then doing them right is the key to management success.

Selecting the Right Things to Do

The following sections have been adapted from White, L. D. (1987a, 1987b) and White, L. D. et al. (1987).

Ranching and farming is many things to many people due to unique resources, personal goals, experiences, and environmental conditions. Success, like beauty, "is in the eye of the beholder." Because of the differences between individuals, a single definition or set of values cannot define successful ranching or farming. Farmers and ranchers must define success for their own operations.

Ranch/farm goals identify the desirable objectives to be achieved through management and use of available and future resources. If objectives are achieved, the work is successful. However, goals and objectives for survival are often confused with enterprise objectives and management decisions.

A decisionmaking sequence for selecting the right things to do, shown below, serves as the basic structure for developing an intelligent plan based on resources available and ranch and farm goals. Rather than deciding what to do, a manager first identifies needed responses then selects the most appropriate way to achieve those responses. What management achieves is more important than what is done.

Strategic Ranch Goals Prioritized

↓

Available Ranch Resources

↓

Select Appropriate Enterprises

↓

Enterprise Plans
(Production Calendar)

↓

Flow of Resources
(Budgets, Cashflow, Stockflow, Grazing Schedule, Etc.)

↓

Implementation And Control
(Monitor Current Conditions and Trends, Compare With Plans)

↓

Adjustments And Re-planning

Selecting the right things to do requires management to plan and evaluate from the strategic goal level (needed responses) through selection of tactical solutions (performance objectives) which determine operational priorities. These are six steps used in the decisionmaking sequence:

1. Strategic ranch goals prioritized.--Strategic goals define success for the ranch. These are what the ranching operation must accomplish over the long-term. Each year certain objectives must be accomplished in order to achieve the strategic goals. These goals identify why you are ranching, not what enterprises are selected nor goals and objectives for effective management of enterprises. Workshops with ranchers have identified four categories of strategic goals (prioritized) as follows:

a. maintain ranch ownership for inheritance to children,

b. meet family living expenses,

c. have adequate security against catastrophic losses, and

d. make profit for investment and ranch improvements.

Most ranchers were not interested in maximizing profit; rather they want to achieve goals A through C, make some improvements and enjoy ranching as a life style. This puts new light on why "good" technologies are not adopted until crisis situations require more intensification. Most new technologies require additional investment, new skills, and more intensive management. As long as a rancher can continue to meet basic wants, why change!

Duerr et al. (1971) has observed that goals can define the information needed for decisionmaking. The lack of a clear-cut and carefully considered statement of objective is one of the most common causes of failure (Fulmer 1974). However, these goals and objectives must be those most important for a operation to succeed in the future. A rancher can be successful at raising livestock but lose the ranch. Selecting the right goals that are achievable is the first step. Ranch and farm resources must be considered since they limit what can be accomplished and cannot be over-extended without deterioration of resources.

All goals should be SMART (i.e., S-specific in what is to be accomplished, M-measurable, A-attainable, R-related to other

ranch goals and use of resources, and T-trackable) (Blanchard et al. 1985). Available ranch resources limit what can be accomplished. Goals that must be accomplished must be prioritized over those that you want to accomplish. Once a higher priority goal is achieved other goals have use of remaining resources. Limiting resources must be effectively allocated and not over-extended beyond recovery.

Goals are achievable through selection of enterprises (investments). Achievable goals require the rancher to utilize enterprises best adapted to ranch resources and meet consumer satisfaction at a reasonable profit. Most ranches require sale of products produced from ranch resources, although off ranch investments may be a wiser choice at times.

2. Available Ranch Resources.--Ranch resources are used through enterprises to produce the responses needed to be successful. A general listing of resources and their capacity to support different enterprises is the first step. As enterprises are selected more specific inventories showing flow of resources are needed to balance resource demand with supply throughout the year. By listing resources and potential enterprises, opportunities to change can be maintained and new enterprises adopted.

Management allocates available resources to enterprises and to maintain or improve future resources. Enterprise production is limited by resource capabilities. For example, to maintain ranch ownership and family withdrawal, the ranch may have an annual overhead cost of $50,000. A cow/calf enterprise that produces a gross margin of $150/animal unit (AU) requires a 334 animal unit range carrying capacity. At a stocking rate of 20 ac./AU-year the minimum ranch size would be 6680 ac. to break even. Gross margin is income above production costs, i.e., contribution to pay overhead. Profit is money remaining after paying all expenses.

If the ranch has additional "overhead" costs (goals and objectives) to be achieved, the cow/calf enterprise is inadequate. The goals and enterprise will have to be re-evaluated.

Overhead expenses cannot be emphasized enough. Most ranchers and farmers do a good job of managing enterprises, but their resources cannot produce enough gross margin. Many investments fail to produce needed increases over long enough time to reduce overhead. Land improvements aimed at increasing enterprise production should be considered as a cost to that enterprise, but once installed they become overhead costs to land ownership that must be paid even if the enterprise is discontinued. Unlike equipment, they cannot be sold with the livestock or crop.

Reducing overhead has a major impact on what enterprises have to produce and how close to the limit resources have to be used. The lower the overhead the more conservatively resources can be used. Profits are often used to make improvements for increased enterprise production, but a better use may be to reduce long-term overhead debt obligations as quickly as possible. When livestock prices increase, it may be an appropriate time to sell, reducing debt (lower overhead), and lease grazing until livestock prices fall. Then stock could be purchased for the next cycle.

3. Select Appropriate Enterprises.--Enterprises should be selected so that resources are effectively used to produce the highest total ranch benefits when combined. Through the allocation of limiting resources, competition is minimized and enterprises effectively convert resources to salable products. The manager must re-direct resources from areas of low or diminishing results to areas of high or increasing results, thereby optimizing the yield from these resources (Drucker 1974).

Diversification can reduce impact of single enterprise cycles, more effectively utilize certain capital improvements and equipment, and mitigate the effects of extreme environmental conditions. However, excessive complexity in a business can cause more things to go wrong. In addition, the more complex a business is, the more difficult it is to determine what went wrong and to make corrections. "No matter how desirable ... diversification is, it has to make possible concentration" (Drucker 1974).

Enterprises require different kinds and quantities of resources over time. Some compete, while others are supplementary or complimentary for use of resources. For example, cattle, sheep, Angora goats and white-tailed deer select different diets and have different gross margins per unit of forage intake. Without over use of any forage component, availability of forage resources (grass, forbs, and browse) will limit proper stocking rates for each enterprise. Because of a variety of forage resources, a single enterprise will result in one component limiting stocking rate while under utilizing remaining forage components. Optimization compares all enterprise combinations to determine the combination producing highest firm gross margin.

Overhead expenses should be reduced if different enterprise combinations cannot achieve these strategic goals in below normal rainfall years. The four factors affecting enterprise gross margin should not be overly optimistic, especially when budgets are tight, to meet critical survival goals. The four factors within each enterprise are:

1. number of production units,
2. production per unit,
3. value per unit, and
4. direct cost of production.

Once these factors are used to achieve a realistic budget they serve as enterprise performance standards (objectives).

A "balance sheet" approach is used in TRM to coordinate planning and implementation. The balance sheet allows a manager to separate components of the operation for detailed planning and combine results to evaluate achievement.

A balance sheet procedure allows managers to evaluate potential risks and gains before making a decision. Such a systematic procedure is needed to assure consideration is given to important aspects of the alternatives (Janis and Mann 1976)

4. Enterprise Production Plans.-These plans identify the necessary activities for the enterprises to effectively convert resources into products sold, thereby achieving the needed performance standards. They also identify resource requirements. Effectively managed enterprises produce the highest benefits

(optimal) from resource inputs. The more effective an enterprise becomes, the more valuable it becomes for investments of limited resources. For example, range improvement practices usually cost the same regardless of enterprise profitability, hence, the practice could be very cost effective or a poor investment, depending on enterprise effectiveness.

"Effectiveness...starts out with the realization that...10% to 15% [of human endeavor] produces 80% to 90% of the results. The other 85% to 90% [of effort], no matter how efficiently taken care of, produces nothing but costs..." (Drucker 1974). Achieving goals effectively requires enterprise plans that, when combined, demonstrate that necessary objectives can be accomplished with due consideration of risk and uncertainty of factors beyond ranch control.

5. Flow of Resources.--Since enterprises require different kinds and quantities of resources over time, resource flow plans are used to identify and budget expected resource availability and use. This allows a rancher to ration seasonal surpluses for periods when resource inflow will be inadequate to meet demand. Also, the flow plans serve as the basic monitoring tools to avoid crisis situations.

The budget and resource flow plans are the primary planning and control tools for enterprise management. The expected responses and conditions compared to the actual situation during implementation help identify when decisions are needed. Past and present records are invaluable for forecasting enterprise results, resource demands, and resource availability.

The budget process (allocating resources) serves three purposes: (1) To develop a plan that realistically will allow goal achievement; (2) identify necessary objectives (factors) that, when combined, produce the necessary results; and (3) identify enterprise performance standards and resource needs for management control. The budget summarizes enterprise management plans in numerical terms.

Partial budgeting should be used to compare alternatives. This identifies the most effective use of the available resource. If a practice has several years longevity, a partial budget is performed for each year. The present value of the net change for each year is summed to determine total present value for the investment. An acceptable interest rate is used to determine present value. The investment with the highest total present value generally is a more effective use of resources; however, flexibility and diversity to change may be invaluable, thus an alternative with lower present value may be selected based on future expectations.

Effective planning forces the rancher to analyze assumptions and eliminate, as much as possible, the elements of chance...and recognize factors that cannot be predicted or controlled. If the plan will not support the added costs of overcoming unexpected conditions, it is incomplete (Fulmer 1974). A plan that allows meeting overhead expenses should be developed for drought and poor market years; then profits in good years will be available for investments and survival is more likely.

The management plan identifies when and where certain events are expected to be completed, producing desired results under expected conditions. Completion dates are an integral part of any schedule. In addition, however, the manager should designate intermediate attainment standards, sometimes called mileposts. Such standards allow an ongoing appraisal of progress, helping to evaluate whether objectives will be achieved (Fulmer 1974). These operational level plans identify the flow of resources by enterprise, grazing unit, field, etc.

The cashflow, stockflow, grazing schedule and forage inventory, labor calendar, and production calendars identify expected and actual availability, allocation (and rationing), supply/demand balance, sources, and timetable for flow of ranch resources. Similar schedules can be developed for various farming operations and crops. Conflicts and shortages are resolved through the planning process. These planning calendars identify expected monthly status of resources, thus serving as mileposts to monitor progress for achieving objectives and to forecast potential crisis situations.

6. Implementation and Control.--Management with good plans and current information can be more effectively implemented and controlled. Good planning already demonstrates the feasibility to accomplish strategic goals. Once a workable plan is developed, day-to-day operations use these to compare with current and forecast resource flows to select priority activities and evaluate alternatives. Alternative courses of action can be evaluated before crisis situations develop.

Flow plans identify periodic mileposts for monitoring progress and trends, thus helping to prevent crisis situations through evaluation of alternatives. Through this process a rancher is better prepared to take advantage of opportunities before his or her competitors.

Accurate records showing actual resource flows serve as valuable information for future planning. Ranchers who do not have a good record of what happened only know end of year results and can make few improved management decisions.

Time allocation for developing plans, etc., must be a high priority. Otherwise, the many daily chores begin to run the business. There are always more things that need to be done or checked than time available. The TRM approach will help a rancher prioritize allocation of this non-renewable resource. Time for a ranch can only be increased by hiring more personnel, an expensive option. Therefore, personnel should be achieving needed responses rather than just working hard. Daily priorities for selecting the right things to do are based on these operational plans.

Knowing how each of the operational plans combine to affect strategic goal achievement and potential future resources helps the manager to better visualize when situations require decisions. These plans serve as monitoring and control tools to be used on a regular basis. Periodic inventory of actual conditions and use of past information concerning "normal" conditions and revised expectations of future conditions are used to readjust decisions.

More intensive management requires more frequent evaluations and decisions. Collect only the information needed. Managers can spend all their time collecting and analyzing information and fail to ranch or farm. Since cash flow summa-

rizes results of other plans, it should be updated monthly. Discrepancies will indicate the probable source. The probable cause can be tracked from the cashflow through the various plans. A daily diary of activities and observations helps better pinpoint causes.

Summary

Through this total ranch management (TRM) planning process a manager knows the economic position and ultimate goals of his or her ranching operation, as well as a plan for attaining the latter. By evaluating alternatives using economic and other criteria and measuring potential impact of decisions on resource flows and goal attainment, managers can better select the right things to do. Then, the plan must be implemented and technologies properly applied.

Selecting the right things to do requires management to develop a TRM plan from the top down to daily operations for effective use of all resources.

"Good management is the effective use of resources to accomplish the most important objectives in your ranch business...in light of the environment and competition...recognizing your relative strengths, weaknesses, and opportunities...with due consideration of assumptions or factors which cannot be predicted with accuracy...in line with consistent policies...through specific programs and projects" (Maddux 1984).

Successes and failures will continue to impact all ranchers and farmers, but the real impact will differ depending on selected goals, available resources and thoroughness of management. Most ranchers and farmers today are faced with increasingly frequent crisis management decisions. Ranchers and farmers should, after implementing a TRM plan, feel more in control of their ranch or farm and its future.

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The Effects of Different Production Systems, Technology Mixes, and Farming Practices on Farm Size and Communities: Implications for the Conservation Reserve Program

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Abstract.--The paper explores the relation between farming and rural community vitality, emphasizing Great Plains farming dependent counties, and examines the impact of farm-size change and the current farm crisis on county-level sectoral income and employment, retail trade, population, etc. The influence of the retail merchandising revolution and growing transfer payments, and the Conservation Reserve Program on rural communities are also discussed.

The objectives of this paper are (1) to examine the impact of farm size and farming systems on farming dependent communities in the Great Plains and West, (2) to explore the effect of declining farm income and of expanding farm programs, transfer payments and a growing service sector on farming dependent community vitality, and (3) based on what is presented under 1 and 2, to speculate on the economic effects of the Conservation Reserve Program (CRP) on farmers and farming communities.

Farm Size, Farming Systems, and Vitality of Farming Dependent Communities

Farming Systems and Community Vitality

In 1985, we conducted a study for the Office of Technology Assessment of the U.S. Congress (Flora and Flora 1986) which examined the impact of changing farm size on the vitality of farming dependent counties in the Great Plains and the West. We examined counties located in primarily agricultural and in federal land counties which have a strong agricultural component. The analysis was limited to those counties whose agriculture is currently dominated by small grains or livestock or both. Farming dependent counties were defined by Bender et al. (1985), as being those in which at least 20% of personal income in the period 1975-79 came from farming proprietor or labor income. A small number of cases were added that did not qualify under the above mentioned criteria, but did have at least 25% of their labor force in farming. Counties that obtained 25% or more of their production value from dairying, poultry, cotton, potatoes, sugar beets, rice, vegetables, and fruits, and oil seeds were eliminated from the analysis. Counties on the eastern edge of the area that had predominately corn belt agricultural systems (consisting chiefly of coon, soybeans, and hogs) were also eliminated from the analysis.

The farming system predominating in each county was determined using crop and livestock data from the 1974 and 1982 agricultural censuses. Initial analysis indicated that irrigation was important in a number of the counties, but the presence of irrigation was reflected in the emergent farming system. With irrigation, small grain/livestock counties tended to diversify into mixed grain/livestock systems, with corn and sorghum replacing wheat and milo. Alternatively, livestock counties increased hay production for cold weather feeding where irrigation was available. Thus, four major farming systems were identified for analysis: wheat, livestock, small grains/livestock, and mixed crops/livestock. The livestock and small grain/livestock counties

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had cow/calf operations and in some instances ewe/lamb operations, while the livestock in mixed crop/livestock were chiefly feedlot cattle. Separate analyses were conducted for each of the four farming systems types, as we wanted to control the effects of farming system on the relationship between farm size and community vitality. In the end, all four farming systems types were combined when it was found that the direction of the relationships was similar for each.

The one type of farming system that was somewhat different from the others was the livestock counties, where stock cattle or ewe/lamb operations predominated (Flora and Flora 1987). Using cross-sectional analysis, we found that prior to the 1970s the livestock counties were least likely to generate economically healthy communities and prosperous families. They were characterized by a smaller population, fewer retail and wholesale establishments, lower median family income, and a larger proportion of the population in poverty (table 1). The explanation for this difference in quality of life is that livestock ranching requires fewer inputs and, generally, population is less dense in these counties. The income multiplier within the community is low because there is a tendency for ranchers to buy inputs and consumer goods extra-locally. This is partly because more ranchers have something other than farming as their principal occupation, suggesting greater absenteeism than is true for the other three types of farming.

The decline in retail services during the 1970s was least in the livestock counties. They showed the greatest improvement in income and the greatest reduction in poverty. Moreover, livestock counties showed population growth of approximately 5% over the decade, while the other types declined slightly in population. The population growth in the livestock counties occurred largely in the rural non-farm sector. In addition, retail sales volume actually increased somewhat in the livestock counties while it declined substantially in all three of the other types of counties. Poverty declined more rapidly in the livestock counties.

A partial explanation for the narrowing of the differences between the livestock and other farming-dependent counties is that the livestock system is one which has low management input; hence, technological change was the least of any of the county types, and the bypassing of the local community in the purchase of inputs and in consumer shopping did not increase substantially since it had already been occurring to a large degree. Also, for reasons apparently unrelated to agricultural change, livestock counties experienced growth in rural non-farm population. In the other three types of counties, the centralization of merchandising as part of the restructuring of rural retail trade had a strong negative effect on retail trade.

Thus, it may be concluded that the comparative disadvantage of livestock counties in terms of their supporting of viable communities diminished relative to the other farming systems types during the 1970s. The notable differences between livestock and other farming dependent counties prior to the 1970s shows the utility of taking farming system into account when examining the relationship of agriculture to rural community change.

Table 1.-- Socioeconomic and demographic characteristics of the population in livestock and other agricultural counties in the Great Plains and western U.S., 1969-1979 (from Flora and Flora 1986).

Socioeconomic variables	Livestock counties*	Other agricultural counties*
Total county population, 1970	4188	5488
Percent change in rural farm population, 1970-80	-20%	-26%
Percent change in rural nonfarm population, 1970-80	+31%	+15%
Percent change in total population, 1970-80	+5.1%	-1.5%
Operators whose principal occupation is farming, 1978	65%	79%
Retail establishments/1000 population, 1967	13.5	14.7
Percent change in # of retail establishments, 1967-77	-8%	-15%
Retail sales per capital, 1967 (in 1977 dollars)	$1937	$2819
Percent change in retail sales volume, 1967-77	+3%	-11%
Median family income, 1969 (in 1979 dollars)	$12,760	$14,287
Families below poverty, 1969	19%	14%
Change in % of families below poverty, 1969-78	-2.8%	-0.8%
Number of cases	(84)	(150)

**Means of county averages.*

Farm Size and Community Vitality

It is important to note that the time period examined in this study (Flora and Flora 1986) was very unusual in American agricultural history. In general, the 1970s was a period of high agricultural prices, expanding exports, readily available capital, and booming land prices.

Utilizing the 1969 and 1978 agricultural censuses, the independent variables were defined as (1) change in medium-sized farms (farms between 500 and 1,000 acres), and (2) change in number of large farms (those of 2,000 or more acres). The results were as follows:

The change in number of medium-sized farms was positively associated with local purchasing, while change in number of large farms was negatively associated with local purchasing (fig. 1). The dependent variables which measured purchasing within the county were "change in number of retail firms" and "change in retail sales." The reason for this positive relationship between

medium sized farms and local retail activity and the negative relationship between the growth of large farms and retail activity are the following:

1. Medium sized farmers tended to buy locally, while large farmers bought in bulk, thus bypassing the local merchants.

2. Counties with growth in large farms were more likely to have absentee farm operators who did not shop locally or who had operators who did their consumer purchasing and recreating outside the community.

3. Medium sized farms tended to use more labor per unit of agricultural product than did large farms, which were more likely to substitute capital for labor. There was a 66% increase in the average number of hired workers per farm over the decade. However, our analysis suggested that the substitution of capital for labor, phenomenon of the post-world war period, had by the 1970s begun to level off. By 1978, the average farm in the 234 counties studied hired .45 of a worker for more than 150 days of the year.

A change in medium sized farms was positively associated with population maintenance, as measured by the total population of the county and the rural non-farm population (fig. 2). Rural farm population continued to decline regardless of the change in farm structure. This suggests an important conclusion: The superior multiplier effect of medium sized farms operates largely through non-farm job generation rather than through the maintenance of a larger number of farmers in the community. In other words, the economic vitality of communities having a

Figure 1.--Change in retail establishments by change in number of large and medium farms.

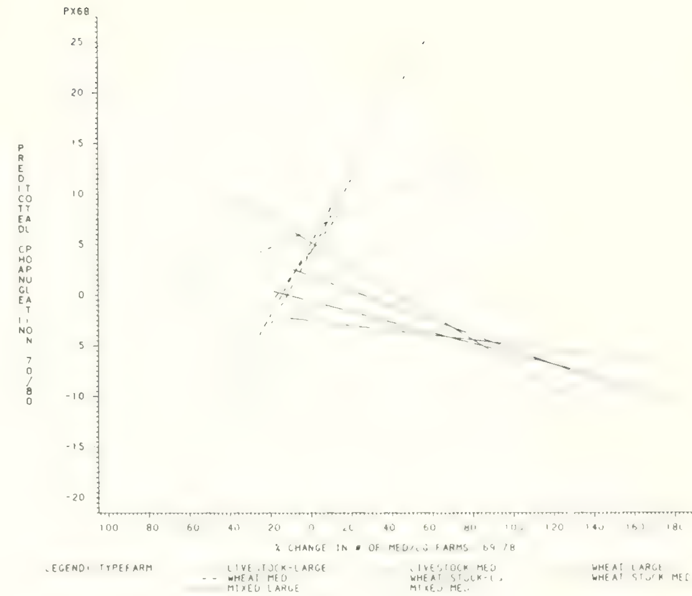

Figure 2.--Change in total county population by change in number of large and medium farms.

predominance of moderate-sized farms is due more to the buying habits of moderate-sized farmers than to a larger farm population in medium-sized agriculture compared to large-farm agriculture.

The maintenance of medium-sized farms was associated with growth in full ownership of farms, while growth in large farms was more associated with partial ownership (Flora and Flora, 1986). In order to understand these results, it is useful to introduce the concepts of yeoman and entrepreneurial farmers developed by Salamon (1985). One must also take into consideration that, although there was an overall decline in full ownership of farms by farm operators in the counties examined, the easy money situation of the 1970s tempted some moderate-sized farmers to purchase land they had been renting.

Moderate-sized agriculture is likely to have a larger proportion of yeoman farmers than is large-scale agriculture (table 2). Yeoman farmers have as their principal objective the passing of a viable farm to the next generation, while entrepreneurial farmers seek to combine land ownership and rental in such a way as to maximize profit in any given year. In simplified terms, entrepreneurial farmers view farming as a business, while yeoman farmers view it as a way of life.

The consequences of the purchase of land by moderate size farmers in the 1970s was sometimes disastrous when the rules of the game began to change in 1979. As a result of tight money, real interest rates rose and the inflated price of land began to fall precipitously. Farmers who were heavily in debt found much of the collateral that backed up those loans had evaporated. Many entrepreneurial farms who had leveraged themselves and chosen input-intensive cultural practices got caught, along with yeoman farmers who were seeking to purchase land so that they would own the entire farm to be passed on to the next generation. This was perhaps the most tragic part of the farm crisis. Not only were

Table 2.--A typology of farming types, modified from Salamon (1985).

Yeoman	Entrepreneur
Goals	
Reproduce a viable farm and at least one farmer in each generation	Manage a well-run business that optimizes short-run financial returns
Strategy	
Ownership of land farmed preferred	Ownership plus rental land to best utilize equipment
Diversify to use land and family most creatively	Manage the most efficient operation possible
Farming organization	
Smaller than average operations	Larger than average operations
Animals plus variety of crops	Monoculture cash grains
Landowners often operators	Landowners frequently absentee
Community structure	
Village central focus of community	Village declining
Community loyalty	Weak community attachment
Population relatively stable	Population diminishing

young people forced out of farming, but often they took their near-retirement parents with them if those parents had co-signed the real estate note.

By the 1980s, there had been a significant shift from proprietors' income to renters' income in agriculture (table 3). Because of the change in the factor cost of capital, it is now more profitable to rent than to own. What we cannot be sure of is whether there has been a move since the early 1980s toward a renter class (as opposed to part ownership-part rental) as occurred in the depression of the 1930s.

Table 3.-- Percentage of total personal income from farm income and property income, 46 farming dependent counties of Kansas, 1979, 1982, and 1985.[1]

Type of Income	1979	1982	1985
Proprietors' Farm Income[2]	29	20	20
Rent, interest, and dividends	20	28	27

[1]Calculated from U.S. Department of Commerce. Bureau of Economic analysis. 1986. Local Area Personal Income, 1979-84. Volume 1. Washington, D.C.: U.S. Government Printing Office.

[2]Includes direct farm program payments.

Declining Farm Income, Growing Farm Programs, Transfer Payments and Farming Dependent Communities

From the vantage point of the late 1980s, it is clear that rural communities are in trouble. The farm crisis, instability in petroleum prices, and the movement of industry from rural areas have created an air of crisis in diverse rural communities. In addition, relaxation of antitrust and tax laws favoring quick amortization and over-investment in capital goods have taken their toll on rural areas. The only reversal of those tendencies is contained in some features of the 1986 Tax Reform Law. Finally, a retail merchandising revolution has affected rural areas, independent of the other changes which have taken place.

In order to put the relation of agriculture to rural communities in context, it is necessary to look at some of the changes which have taken place in rural communities in the post-World War II period. The most important change has been an employment shift from agriculture to the service sector. Most employment growth has been in the financial sector, professional services, the health system, the educational system, and personal services.

Retail trade is the one category within the service sector which is not growing in the 1980s. For example, in Kansas the farming dependent counties experienced the greatest decline in retail sales of any category of counties - an approximate 4% annual decline in retail sales (table 4).

Why did such a sharp decline in retail sales occur in the farming dependent counties? It is clear that agriculturally related establishments, such as machinery dealerships and feed and fertilizer stores experienced a greater decline in sales for the period 1979-85 than did non-agriculturally related establishments, or those which could not be classified clearly as farm related or non-farm related establishments, such as construction firms, hardwares, garages and auto accessories firms, etc. (table 5). Furthermore, in the farming-dependent counties, agriculturally related establishments showed greater declines than they did in the nonfarming dependent counties. The mixed retail establishments also declined substantially less in the nonfarming dependent counties, in part because they were not as closely linked to agriculture as they were in the farming dependent counties. Thus, we have substantial evidence to indicate that the farm crisis has had an impact on retail sales, particularly in the farming dependent counties.

There are, however, categories of establishments which showed substantial gains in the farming dependent counties (table 6). Those include department and discount stores, office equipment establishments, and grocery and meat stores, among others. Department and discount establishments experienced a tripling of their sales during this time period. This phenomenon is what we might call the Wal-Marting of rural America. The real increase in sales of 29% by grocery and mean stores from 1979 to 1985 may be called the Seven-Elevening of rural America. There was also a rush in rural Kansas to buy computers in the early 1980s; farmers and local business persons sought them as a way to save their declining businesses. In interviews with business persons in one community in 1985, we learned that

Table 4.-- Change in total sales of all establishments by type of Kansas county, 1979-85. Taken from Kansas Department of Revenue sales tax data.

County type	% change in sales[1] 1979-1982	1982-1985	1979-1985
Farming dependent (46)[2]	-14	-13	-24
Other commodity dependent (7)	+24	-27	-10
Other Non-metro: (44)	-7	-8	-14
Service centers with commodity-dependent trade areas (10)	+2	-10	-7
Metro (8)	-8	+8	-0
State totals (105)	-7	-0	-8

[1] *Based on 1985 dollars.*

[2] *No. of counties.*

Table 5.-- Change in sales for agriculturally-related, mixed, and non-agriculturally-related establishments, Kansas Counties, 1979-85.[1] From Kansas Department of Revenue sales tax data.

Type of establishment	% change in sales[2] 1979-1982	1982-1985	1979-1985
Farming dependent counties (N=46):			
Agriculturally related establishments	-19	-33	-45
Mixed establishments	-7	-11	-17
Non-ag-related establishments	-12	-1	-13
Metro counties & other non-farming dependent counties (N=59):			
Ag-related establishments	-9	-23	-31
Mixed establishments	-2	1	-1
Non-ag-related establishments	-13	11	-3

[1] *The following kinds of establishments were defined as being agriculturally related: Blacksmith and welding shops; farm implement dealers; and flour, feed, grain, and fertilizer firms.*

Mixed establishments: accessories, tire and battery firms; and garage and repair shops; hardware and paint stores and rentals, and all manufacturing and trading firms; except printing and publishing.

Non-agriculturally related establishments: all apparel firms; all automotive firms, except accessories, tires, and battery firms, and garages and repair shops; all food-related establishments; all furniture-related establishments; all general merchandise establishments, except hardware and paint stores; public utilities; all personal and professional services; and printing and publishing firms, and most "unclassified" firms.

[2] *In 1985 dollars.*

Table 6.-- Change in sales of specific types of establishments, 46 farming-dependent counties of Kansas, 1979-85. From Kansas Department of Revenue sales tax data.

Type of establishment	Change in sales[1] 1979-1982	1982-1985	1979-1985 (percent)
Substantial growth			
Department and discount stores	+	+	+213
Dance, theaters, parks	-	+	+97
Variety and gift shops	0[2]	+	+59
Machinery, tools	+	+	+42
Office equipment	+	-	+32
Grocery and meat stores	0	+	+29
Substantial decline: Agriculturally related			
Metal products, pipe and steel	-	-	-71
Chemicals and products	0	-	-70
Farm implements	-	-	-47
Flour, feed, grain and fertilizer	-	-	-43
Electric equipment and supplies	-	-	-41
Building materials - new and used	-	-	-39
Hardware and paint stores	-	-	-36
Blacksmiths and welders	0	-	-32
Lumber and building	-	-	-30
Substantial decline: Other			
Cable TV, radio service	+	-	-100
Barber and beauty shops	+	-	-71
Jewelry stores	-	-	-66
Laundry and dry cleaners	+	-	-49
Automotive	-	-	-40
Lease and rentals	0	-	-40
Drug stores	-	-	-33
Filling and service stations	-	0	-32
Undertakers and funeral parlors	+	-	-30
Auto dealers and mobile homes	-	0	-29
Mens and boys clothing	-	0	-26

[1] *In 1985 dollars.*

[2] *0 in first two columns means a change of less than 10%.*

Note: Types of establishment with a change of less than 25% were omitted.

many retailers were using computers to better manage their accounts receivable.

While farming dependent counties were experiencing sharp declines in retail sales, the service center counties serving them were not declining nearly as rapidly. From 1979 to 1982, farming dependent counties in Kansas experienced an annual 5% decrease in retail sales, but the service center counties serving those areas experienced nearly a 1% annual increase. For the entire

period of 1979-85, the decline in retail trade in the service center counties was one third that of the farming dependent counties (table 4). This clearly suggests that there is a process of concentration of merchandising, resulting in the boarding up of many locally-owned mainstreet businesses in the farming dependent counties. At the same time, they are often being replaced in the nearby service center county by nationally-based merchandising firms. While the centralization of retail merchandising took place in metropolitan America in the 1950s and 60s, it is an unhappy coincidence that it is occurring in rural American during a time of economic distress.

Despite the problems experienced by farming dependent communities, by 1984 total per capita real income in the farming dependent counties of Kansas exceeded that of the state as a whole and approached the level of 1979 (table 7). The 5-year statistics are characterized by tremendous swings in real farm income in those counties, however. The sharp increase in real farm income between 1983-84 marks the engagement of the farm program and the substantial amount of PIK payments which began to fill the pockets of farmers in 1983 (fig. 3).

In addition there has been a substantial increase in transfer payments first to Kansas as a whole and particularly to rural Kansas communities in the period 1979 to 1985. The state as a whole showed approximately a 5% annual rate of growth in transfer payment receipts, which includes retirement payments, medical and disability, and income maintenance programs. In 1985, farming-dependent counties received nearly 17% of their total personal income from transfer payments (up from 12% in 1979), and non-metropolitan oil-dependent and manufacturing counties received an even higher proportion of their income through transfer payments (table 8).

The fact that these types of counties received a larger than expected share of the state's transfer payments is due principally to the age structure of the counties. Many farming dependent counties have over 20% of their population over 65, more than double their percentage at the beginning of World War II. When the transfer payments are added to farm payments, which since 1983 represent over half of net farm income in the farming dependent counties, it is apparent that governmental payments represent a substantial portion of county income in the mid 1980s. Figure 3 suggests that the farm payments may decline substantially in the next few years. Thus, the apparent well-being of farming dependent counties may change substantially, since the prospects for improved market prices for major commodities are not good, even though the dollar has experienced a substantial decline vis-a-vis the other major currencies over the past two years.

On the other hand, transfer payments can be counted upon to remain stable, if not to increase slightly. Communities that value their elderly citizens and set out to improve their quality of life, as well as citizens in general, will, if they work creatively, expand the numbers of jobs in rural communities more readily than

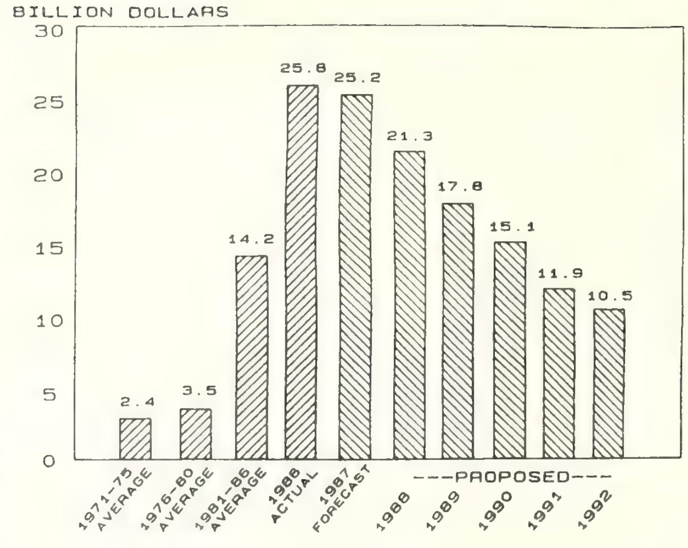

Figure 3.--Net outlays for U.S. farm programs.

Table 7.--Changes (in percent) in farm and per capita income, 46 farming dependent counties of Kansas, 1979-84.[1]

		1979-1980	1980-1981	1981-1982	1982-1983	1983-1984
Change in real farm income (46 counties)		-53	+49	-10	-36	+70
Real per capita income[2]	1979	1980	1981	1982	1983	1984
			(thousands of dollars)[2]			
Farming dependent counties (N=46)	14.5	12.3	13.8	13.6	12.7	14.4
Kansas	13.6	12.8	13.0	13.1	13.0	13.8

[1]*U.S. Department of Commerce. Bureau of Economic Analysis. 1986. Local Area Personal Income, 1979-84. Volume 1. Washington, D.C. Government Printing Office.*

[2]*In 1985 dollars.*

Table 8.-- Percentage of total personal income represented by transfer payments, selected groups of counties, Kansas, 1985. From U.S. Department of Commerce, Bureau of Agricultural Economics. Transfer payments tape.

County group	
All non-metro counties (97)[1]	16.7
Farming dependent (46)	16.6
Petroleum dependent (7)	19.5
All metropolitan counties (8)	11.3
Kansas (105)	13.7

[1]*Number of countries.*

through efforts to expand markets for major agricultural commodities or providing incentives to industrial firms to locate in their communities. Unlike deficiency payments, the payments from the CRP, at least for the next 10 years, can be depended upon as a stable form of income to farming-dependent communities, much as social security can be depended upon.

Effects of the Conservation Reserve Program on Farmers and Communities

The impact of the Conservation Reserve Program on communities must be assessed in a two-step process: we must first examine its effects on farmers; then we can surmise its impact on communities. The impact will vary by type of farming system.

Effects on Farmers

The CRP will definitely contribute to the stabilization of farmers' incomes. The direct effects are not unlike those of deficiency payments and other parts of the farm program. The critical difference is that the level of payments through the CRP can be anticipated for a 10-year period, thus allowing farmers to engage in long term planning. Levels of deficiency payments for the short term -- and certainly for the medium term -- are subject to political determination.

Indirect effects of the CRP, through prices of agricultural commodities, will likely be negligible. Taking highly erodible and fragile land out of crop production is not likely to significantly affect the current oversupply of the major farm-program commodities. This, of course, assumes that the CRP is not expanded to become an income support program to replace deficiency payments as they are gradually phased out. Yield-enhancing inputs will be concentrated on the better land kept in cultivation and per farm output is likely to drop very little, except in cases where most or all of the farm is put in the CRP.

Diversification of income is highly related to income stabilization. The income from the CRP can be viewed as comparable to the raising of an additional crop -- one for which yields and income are not cyclical during the 10-year period of the program. Though income from wheat, corn, or soybeans may dip in a particular year, the farmer can plan for income from land in the CRP. It is unclear how stabilization and diversification of income in this modest "farm enterprise" will affect farmers' decision-making in other enterprises and off-farm activities. That undoubtedly depends on the kind of farmer and farming system.

It is likely that the CRP will be more creatively used by the yeoman farmer over the entrepreneurial farmer (table 2). This is particularly true if the CRP becomes the dominant form of farm subsidy payments, e.g., should deficiency payments be gradually reduced or phased out. There are a number of reasons for this:

1. Yeoman farmers are more likely to be located in areas where the subsidized commodities are not dominant and to have combined crop and livestock operations; farm payments go disproportionately to large farmers, who tend to be entrepreneurial and are more likely to be specialized.
2. If they are in an area where the major subsidized commodities are grown, yeoman farmers are more likely to diversify their crop and livestock production if non-conservation related farm payments are reduced to the point that farmers are released from the necessity of growing subsidized crops. Entrepreneurial farmers are likely to continue to keep the simpler farming systems, even if the prices of wheat, corn, soybeans, and cotton remain low. Yeoman farmers are more interested in risk reduction, and the CRP offers that.
3. Since it is the entrepreneurial farmers who are more prone to be in financial difficulty (Jenkins 1986), substantial numbers of this group will go out of business. Yeoman farmers will benefit more from the CRP merely because a higher percentage of them will remain in farming. CRP payments are not likely to have a significant impact on keeping farmers from going out of business because of heavy indebtedness.
4. A wild card is whether the added income from the CRP will facilitate purchases of additional land by entrepreneurial farmers with no significant debt. We need to examine the behavior of out-of-debt farmers currently in the farm program to determine if they are buying land with the income from deficiency payments.

Part-time farmers will benefit from the CRP more than larger farmers. It will release them from part of their farm work so family members can work more hours off-farm, or it will provide a nest egg which can be used for investment in more intensive farm production, perhaps the adding of a new enterprise. Thus, the CRP can be expected to modestly strengthen the competitiveness of certain smaller, part-time farms. This generalization will not be applicable in the areas of the Great Plains where the largest amount of erodable land is located, since those tend to also be areas where population density is low and alternate employment is scarce.

Effects on Communities

The impact of the CRP on communities will not be great, except in areas with large amounts of highly erodible land, such as in parts of the western Great Plains, simply because the income effects of the CRP will be substantially less than the current impact of other farm payments, particularly deficiency payments. Nonetheless, some impacts can be discerned.

CRP payments, as at the farmer level, will provide steady income to the community for a 10-year period. Such payments are more like social security payments than deficiency payments

in their effect on the community because of their greater long-term stability. The important questions regarding their stimulation of the community's economy include the following:

From earlier studies, we already know that farming has a greater positive economic impact on the community in medium-farm communities than in large-farm communities. More of CRP payments will be circulated in the local community if it is a medium-farm rather than a large farm community.

Medium farm communities have a higher proportion of owner-operated farms than do large farm communities. CRP payments are supposed to be divided between landlord and tenant in proportion to their share of the crop. Apparently the norm is that the cost of seed, seedbed preparation, and planting also be divided in the same proportion, although that can be negotiated between the two parties. In the case of cash rent, both cost and benefit are to accrue to the tenant.

Local ASCS committees (composed of three farmers who collectively know the farms in the county pretty well) are supposed to guard against a landlord evicting a tenant, signing up for the conservation reserve, and then renting only the land not in the conservation reserve to a new tenant. In the more egalitarian Great Plains, it is likely that there will be few abuses which deprive the tenant of CRP payments. Where there is substantial social distance, as in the South, tenants may find themselves divested of CRP payments, just as they were deprived of AAA payments in the 1930s.

The rules parallel those for division of deficiency payments, but the potential for abuse is greater, since the land is taken out of production permanently, and therefore it is easier to divorce production from payments. This will occur particularly where farmers decide to retire and put land in the CRP before turning the farm over to the renter. Should the retired farmer choose to retire in Arizona or California, those payments will be lost to the community and the region. Additional research is needed to ascertain whether this practice is taking place to a significant degree. Results from such research should also have implications for assessment of leakage from the community of CRP payments.

The capacity to turn over money within the community may vary by distance from a metropolitan center or service center, community spirit, aggressiveness of local business persons, population density of the area, and other factors.

The CRP will have a negative impact on sales of input suppliers. Perhaps the impact on the sale of machinery will not be great, since most farmers will still need about the same array of tractors, harvesters, and other implements that they previously had. In the short term, anything which puts money in farmers' pockets is likely to contribute to increased machinery sales, since farmers have long delayed replacing old machinery. However, they may move to machinery rental, as the tendency to over-capitalize, spurred by tax breaks, has been reversed. This will change the nature of machinery dealerships.

Where whole farms go into the CRP or where the maximum proportion of cultivated land which can enter the CRP is raised to 35% or perhaps more, there may be a serious decline in input purchases and a crisis may arise in associated communities.

Decline in tractor fuel and spare parts sales is likely to be proportional to the decline in land in crops as a result of participation in the CRP. Fertilizer sales will decline less in areas where farm-program commodities are grown if deficiency payments are substantial, because farmers will tend to fertilize reduced planted acres more heavily. Pesticide sales may decline, depending on whether the CRP acres are hosts to pests which attack adjacent crops. However, consumer services should be enhanced by the added transfer payments available to the community.

Given the depressed farm economy and prospects for its continuation, the CRP should have a positive impact on retail trade and general economic activity in most rural communities. Unfortunately, the restructuring of the U.S. economy and the malling and Wal-Marting of rural America will more than offset whatever positive effects the CRP may have, while the CRP's negative impact will be clearly noted in areas with a high proportion of erodible land. In certain areas where CRP land provides habitat for wild game, there may be positive income impacts from lease hunting and from hunters' purchases in the community. This is not likely to occur on a significant scale in the more arid parts of the Great Plains.

In the long run, we hypothesize that healthy communities and ecologically sound treatment of the land will go together We propose that yeoman farmers will be more likely to keep land in a conservation reserve regardless of government incentives, just as they are more likely than entrepreneurial farmers to shop locally and to support local schools and hospitals. Studies which attempt to explain conservation behavior generally find little or no difference between owners and renters, farmers' educational levels, and other socioeconomic variables (Carlson, Dillman and Lassey 1981, Ervin 1986, Hooks et al. 1983, Korsching et al. 1983, Nowak and Korsching 1983).

Napier, et al. 1986, found that, as the scale of farming operations increased, soil conservation practices were used somewhat less frequently. Farmers with integrated crop and livestock operations used conservation practices more often. Highly capitalized grain producers were less likely to use conservation tillage practices (Napier et al. 1984). These results are consistent with the hypothesized relationship between yeoman agriculture and conservation behavior. Flora (1987) reviewed the results of these and other conservation behavior studies.

Perhaps the yeoman-entrepreneur dichotomy will be a better predictor of conservation behavior than are traditional socioeconomic variables. Commitment to farming as a way of life implies a long term view as does conservation behavior.

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Anticipated Changes in Rural Communities Due to Financial Stress in Agriculture: Implications for Conservation Programs

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Abstract.--Existing literature focusing on the farm financial crisis is examined in the context of possible impacts on individual land operators and rural communities. Potential environmental consequences of the farm crisis are noted and policy implications discussed.

Rural residents throughout the United States are being subjected to many change forces that will undoubtedly result in modifications in the social structure of affected communities and in the life styles of people living within them. The stimuli for change range from rural industrial development to loss of service function.

Each stimulus for change has somewhat different impacts on community groups. Some change forces have very significant and long-term impacts, while others have relatively minor influence and are short-lived. Given the variability of impacts associated with different stimuli for change, it is very difficult to predict specific outcomes of change forces on community groups. However, knowledge of existing social impact assessment research combined with awareness of situational conditions of rural populations provide a means of anticipating what some of the impacts will be on affected groups.

One of the most important change forces presently affecting rural populations within the United States is the financial crisis in agriculture. The socioeconomic consequences of the farm financial crisis have the potential to influence rural life and living for several decades. The purpose of this paper is to provide a general overview of the factors contributing to financial stress in U.S. agriculture and to employ existing knowledge about social impact assessment to predict possible outcomes on individual land operators and community groups. The potential impacts of the conservation components of the Food Security Act of 1985 for reducing the adverse consequences of the financial stress of farmers and ranchers in the U.S. may be substantial; hence, they have long-term implications worthy of examination.

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The Magnitude of the Financial Problem in U.S. Agriculture

Considerable evidence exists to demonstrate that a substantial number of farmers and ranchers in the U.S. presently have a serious financial problem. Using debt to asset ratios as a measure of economic viability of farming enterprises, research (Petrulis et al. 1987) reveals that approximately 12.7% of all farmers and ranchers in the U.S. have a potential financial problem (debt to asset ratio of 40-70%) and that an additional 4.6% have a very serious problem (debt to asset ratio of greater than 70%).

Land owners with debt to asset ratios above 70% will have considerable difficulty servicing their debt and run serious risk of losing their farms. However, the probability of economic failure declines as the debt to asset ratio decreases in magnitude. Fortunately, the greatest number of financially stressed land operators are in the 40-70% category, which suggests that a large proportion of financially stressed farmers and ranchers will survive with careful economic planning. Petrulis et al. (1987) support this observation when they note that approximately 11.2% of the farmers and ranchers in this society are actually experiencing financial stress. Many of these land operators will survive the financial crisis, suggesting that a relatively small percentage of farmers and ranchers will be forced to leave agriculture in the near future.

The loss of a small percentage of farmers and ranchers will not seriously affect U.S. agriculture in the aggregate, but regional and local impacts will probably be significant, at least in the short-run. The socioeconomic impacts of the displacement of debt-ridden land operators will be masked on the national level because the greatest majority of farmers and ranchers will

continue to enjoy relatively good life styles and will have financially secure agricultural operations. Massive poverty among agriculturalists will not be present. Production of food and fiber will not be threatened because the land of displaced farmers and ranchers will be transferred to other owners and will be maintained in production agriculture.

The socioeconomic impacts of the farm crisis on the regional and local levels will probably be substantial until the restructuring of the agricultural system is complete and community groups have accommodated the changes being introduced. This is particularly true in regions of the U.S. which are presently experiencing disproportionate financial problems in agriculture. Several authors (Brooks et al. 1986; Bultena et al. 1986, Johnson et al. 1986, Murdock et al. 1986) have shown that the Corn Belt, the Northern Plains and the Lake States have disproportionate concentrations of financially stressed land operators. Communities in these areas should prepare for substantial socioeconomic changes in the next few years.

Factors Contributing to the Farm Crisis

To ascertain what some of the potential long-term impacts of the farm financial crisis will be on individual land operators and rural communities, it is necessary to examine the causes of the financial problems. To accomplish this task, it is helpful to examine the structure of agriculture during the past five decades.

Several change forces have been in operation for many years within the U.S. which have culminated in financial stress being experienced by many land operators. Farming has traditionally been characterized as being; (1) based primarily on complex technologies, (2) energy intensive, (3) production oriented, and (4) concerned with efficiency.

Technological innovations combined with a farming system that emphasized specialization resulted in a system of agriculture which placed high value on increasing size of operations. Many agriculturalists observed the success of the high-scale farming approach and began to adopt similar techniques, technologies, and ideologies. American farmers and ranchers accepted the belief that success in agriculture demanded continual expansion of technologies and farm size. High-scale farming became the symbol of American agriculture and became the model which all entrants into the system attempted to emulate.

The rewards received from the high-scale agricultural system were traditionally very high (Napier and Forster 1982, Swanson et al. 1986). Productivity and efficiency in agriculture increased rapidly, while the demand for labor decreased. Substitution of technologies for labor progressed rapidly. Farmers who did not adopt new technologies or refused to leverage assets to purchase more land soon discovered themselves in a disadvantaged position relative to farmers willing to do so. Farmers and ranchers were continually pressured to expand production to survive in the highly competitive farming system. Survival required adoption of more energy intensive technologies, greater specialization of production, more chemical inputs and more land in production.

Values supporting high-scale forms of agriculture began to emerge and were quickly adopted. American agriculturalists began to accept new value orientations about credit, use of leveraging, orientations about land resources, and farming as a life-style. Conservative use of credit frequently resulted in farmers becoming antiquated in terms of farm technologies and smaller in size relative to other land operators. Farmers and ranchers who were willing to assume greater risk tended to leverage assets and to expand operations. They also frequently prospered. Friends and neighbors who observed the successes of large-scale agriculturalists began to adopt the same approach.

The system described above was seldom challenged because it was so successful in satisfying the production and efficiency criteria used to judge agriculture at the time. Farmers and ranchers continued to expand operations under the assumption that real interest rates (interest rate minus inflation) would remain low. This assumption appeared to be valid because land continued to increase in value and inflation remained relatively high until the late 1970s (Swanson et al. 1986).

Individuals who wished to enter farming in the late 1970s were forced to pay inflated prices for farm land and to assume high and fixed rates of interest on borrowed money. The problem was further compounded by the fact that entering farmers had internalized a desire to adopt the high-scale system which necessitated larger land holdings and the purchase of very expensive technologies. Young farmers were forced by circumstances to become highly leveraged. More established farmers and ranchers who wished to increase their social status also adopted the same expansion strategy. The result was a highly leveraged group of farmers and ranchers who made an incorrect assumption that inflation would remain relatively high and that land values would continue to rise.

Several national and international situations, which were beyond the control of those in agriculture, intervened to invalidate the assumptions made about the future agricultural economy. Inflation was controlled, and the value of the dollar relative to other international currencies increased and remained high, thereby affecting international trade of food and fiber products. Prices for agricultural products remained relatively low, domestic recessionary trends undermined the land market and land values declined substantially. These factors ushered in an era of severe hardship for highly leveraged farmers and ranchers which will be felt for many years.

The Distribution of Costs Associated with the Farm Crisis

Another factor which affects the potential impacts of change stimuli is the distribution of costs and benefits. The social and economic costs associated with the farm crisis, like the costs attached to most changes, have not been equally distributed by region or by socioeconomic group. The differential decline in the value of farm land by region is a good example. Agricultural land in the Corn Belt decreased as much as 50% between 1981 and 1986, while land values in the Lake States and the Northern

Plains declined by approximately 40% during the same time period (Petrulis et al. 1987). Land values in other areas of the country were much less affected.

Real wealth of many farmers and ranchers in the Corn Belt decreased by almost half, which left many with debts that exceeded the value of their farms and ranches. Many agriculturalists in these areas encountered severe financial problems in the 1980s which will ultimately restructure many rural communities and will influence the life-styles of affected people for many years. Similar situations are being observed in the Northern Plains and in the Lake States.

The irony of the present farm crisis is that, while a significant minority is suffering extensively, the majority of land operators have enjoyed some degree of prosperity. A large number of farmers and ranchers who did not leverage their wealth during the growth period of the 1960s and 1970s have remained relatively prosperous during the stressful period of the 1980s. Henderson[2] recently calculated real cash income per farm and demonstrated that farmers and ranchers will enjoy the most prosperous year in 1987 that they have experienced since 1973. This is significant because 1973 is considered to be "the best of times for U.S. farmers in recent years."

It should also be noted that prosperity in agriculture today is not equally distributed by socioeconomic status. Part-time farmers with small land holdings enjoy relatively good economic security as do operators of larger farms and ranches (Brooks et al 1986). Recent research findings strongly suggest that operators of middle size farms and ranches who entered agriculture during the late 1970s and early 1980s are disproportionately represented in the financially stressed agricultural group.

Total family income for different agricultural groups tends to reflect recent trends. Income data indicate that part-time farmers and ranchers have more family income than middle size farmers because nonfarm jobs are subsidizing farming operations (Brooks et al. 1986). Large-scale farmers and ranchers have the highest income levels due to longer tenure in farming and lower debt to asset ratios. Household income of part-time farmers and large-scale land operators is often above national and regional averages (Brooks et al. 1986).

Examination of the historical factors contributing to the present agricultural financial situation suggests that operators experiencing financial stress at the present time should have the following characteristics: (1) Younger people with few years of farming experience; (2) better educated people who are more recent graduates of an educational system demanding more education than in the past; (3) individuals with greater access to agricultural information systems since they have learned to value scientific information from extension and colleges of agriculture; (4) people with larger families since younger people tend to be in the active years of the family life cycle; and (5) individuals with larger farming operations and gross farm income because leveraging has produced larger operations and greater gross sales.

[2]Personal communication with D. R. Henderson, 1987, Department of Economics and Sociology, The Ohio State University, Columbus.

Recent empirical evidence tends to support these conclusions (Bultena et al. 1986, Henderson and Frank 1985, Murdock et al. 1986). The findings from these and others studies indicate that farmers and ranchers who are most stressed by high debt to asset ratios tend to have the expected characteristics. While the amount of explained variance in the models developed to predict debt to asset ratios has been very low, the patterns have been consistent.

The Potential Social Impacts of the Farm Financial Crisis on Rural Community Groups

The social impacts produced by the agricultural financial crisis vary as a function of the characteristics of the farmers and ranchers experiencing the greatest financial stress and the proportion of resident population directly affected. While community groups are very resilient and can accommodate substantial change (Bowles 1981, Napier 1981, Napier et al. 1986, Savatsky 1986, Summers et al. 1976), they are subject to temporary disequilibrium caused by change forces that exceed their ability to adjust. As the magnitude of the disruption caused by change forces increases, the amount of restructuring required to bring about a relatively stable life style within affected community groups is increased. In the context of the financial crisis noted above, the adverse impacts have been substantial for a specific minority of the farming and ranching community. Agriculturally-based community groups in the Lake States, the Corn Belt and the Northern Plains should prepare for considerable restructuring and an increase in the incidence of social problems.

Some of the potential sociological impacts of the farm financial crisis on communities significantly affected by financial stress are as follows: (1) personal and family problems associated with loss of life style and social status; (2) displacement of farmers and ranchers from agriculture into nonagricultural sectors; (3) possible loss of population due to emigration; (4) decline of local community infrastructures due to loss of population and tax base; (5) increasing scale of local agricultural operations due to purchase of land owned by displaced operators; (6) immigrants to the communities who may be entering agriculture for the first time; (7) exposure of local people to different life styles of recent immigrants; (8) changing leadership due to out- and in-migration; and (9) changed attitudes and values of land operators who remain in agriculture.

Personal and Family Problems

The personal and family problems associated with the farm financial crisis are numerous. Loss of status can result in personal estrangement from family and friends (Napier and Camboni 1987). Deviant behavior in the form of family conflict, substance abuse, and psychological problems may emerge (Hargrove, 1986). The Heffernans (1986) observed extensive pathologies among debt-ridden farmers in Missouri. Financially stressed

farmers were shown to be less involved in leadership roles, exhibited greater depression, and were less frequently in communication with other family members. While the number of families included in the research was relatively small, the study indicated that financial stress contributed to psychosocial problems.

If these types of pathologies become widespread among economically stressed farmers and ranchers, "helping agencies" in rural communities will probably become overwhelmed. The ability of most rural social service agencies to address psychosocial problems on a large scale have traditionally been inadequate. Should social pathologies become problematic on a large scale, limited community development resources will have to be redirected to improve existing support services. Such reallocation of resources will necessitate extensive change in development priorities for most rural communities. Long-term development goals may have to be deferred to provide aid to financially stressed farmers and ranchers who have never before been clients of public social services.

Displacement of Farmers and Ranchers From Agriculture and Structural Impacts

The existing literature suggests that younger, more highly educated people who are operating intermediate size farms and ranches are the most adversely affected by the farm financial crisis. If such people are forced to leave agriculture and their home communities, significant shifts will occur in terms of population characteristics of affected community groups. Rural communities will become older than they presently are which suggests a higher proportion of dependent aged and fewer young people with children. Such population changes suggest that rural communities will have increased problems of financing adequate public services. Community groups will also experience significant shifts in terms of the type of services provided. Past investments in public education could be lost, since the demand for such services would be diminished by emigration of young people with school-aged children. Ultimately, the quality and quantity of several public and private services should be reduced as a result of emigration of young families.

Declining populations will also generate considerable loss of commercial activity in affected communities and could result in the emigration of specialty businesses requiring larger population bases to sustain them. If these changes occur, the trade function of many agriculturally-based communities will be adversely affected.

Immigration should also be expected in some communities affected by the farm financial crisis. Given the relatively low price of agricultural land at the present time, it is highly likely that some people who have been unable to enter farming and ranching due to the inability to purchase land will do so. If outsiders decide to invest in agricultural land, people living in affected rural communities will probably be subject to additional change forces in the form of exposure to different life styles. While research has shown that recent immigrants to disrupted communities are quickly assimilated into restructured groups (Napier et al. 1985), there is a period of disruption for long-term residents. If values, beliefs, attitudes and behavioral patterns of immigrants are substantially different from those of local people, considerable adjustment will be required on the part of long-term residents.

Leadership of community activities may shift significantly as a result of population change. Past leaders may lose their high status in local community groups because they have lost their farms or ranches. Leadership positions may be assumed by recent immigrants or by more prosperous local residents who have never held such positions. In such a situation, extensive change may be introduced as the new leaders assert their influence and restructure priorities.

Changing Values and Attitudes

The farm crisis can adversely affect the basic culture of affected people. Bultena et al. (1986) suggest that some values and attitudes will change as a result of the farm financial crisis. They suggest that perceptions about leveraging by farmers and ranchers who survive the financial crisis will become much more conservative. While this is undoubtedly true, it must be recognized that farmers and ranchers who have prospered during the present situation successfully used leveraging in the past. The major difference between the successful land operator today and those with significant financial stress is that many of the successful farmers and ranchers used leveraging at a different time period and were more conservative in the use of debt. It is highly likely that these people will continue to value use of credit, but only when it is carefully planned and controlled.

Bultena et al. (1986) also suggest that farmers and ranchers will probably become less innovative in terms of the adoption of new technologies. Such an outcome is possible; however, it is also plausible that farmers and ranchers will quickly adopt new innovations that can be expected to provide short-term profits. Innovations in agriculture not capable of producing short-term profits will probably become less attractive.

Bultena et al. (1986) are probably correct that farmers will be more reluctant to adopt new farm technologies that must be purchased with credit. Deficit spending could adversely affect the land operator's ability to accommodate debt load. Farmers and ranchers who were conservative in the use of credit during the 1970s and early 1980s will undoubtedly be more committed to such an orientation in the future.

All of these predictions are based on the assumption that trends in land values will remain basically the same as they are presently or will increase slowly. If land values remain depressed, the scenario outlined above will probably be realized. If land values increase rapidly and commodity prices increase substantially, it is highly likely that traditional patterns of optimism will be embraced by agriculturalists. Old patterns of financing farming operations and willingness to assume risk may once again be adopted.

The Farm Financial Crisis and the Conservation Components of the Food Security Act of 1985

The financial difficulties being experienced by many agriculturalists in the U.S. will have an affect on their future soil conservation orientation. The impact of the financial crisis on volunteer adoption of soil erosion control practices at the farm level will undoubtedly be quite negative. However, the monetary incentives associated with the Conservation Reserve Program (CRP) of the Food Security Act (FSA) of 1985 will encourage adoption of soil erosion control practices in an indirect manner. Unfortunately, the positive impacts of the CRP will probably not be adequate to offset the adverse impacts of the farm financial stress, given the present value orientation of agriculturalists toward investment in soil erosion control practices. Subsequently, the net effect of the farm crisis on the adoption of soil conservation practices at the farm level will probably be negative. The basis for the prediction is presented below.

Many factors have contributed to contemporary soil conservation behaviors of land operators in the U.S. One of the important variables relative to volunteer adoption of soil erosion control practices is perception of responsibility for internalizing the costs of adoption. Recent research conducted in Ohio demonstrated that a large proportion of farmers believed they should not be responsible for assuming the economic costs of adopting soil erosion control practices (Napier and Camboni, 1987). Respondents believed that the cost of agricultural pollution was the responsibility of society rather than individual farmers and ranchers. Such beliefs make it convenient for them to ignore problems caused by soil erosion and to rely heavily on government subsidies to finance adoption of soil control measures at the farm level.

Such findings are consistent with historical evidence. Examination of soil erosion programs in the U.S. strongly suggests that farmers have traditionally been reluctant to invest in soil erosion control practices when there have been significant economic and/or human costs associated with adoption (Camboni and Napier 1986). As the economic and human costs associated with adoption of soil erosion control practices increase, the probability of adoption tends to decrease.

While farmers and ranchers will probably continue to hold positive attitudes toward soil conservation as an abstract concept, many will become even more unwilling to invest personal resources on conservation practices that will not produce offsetting economic returns in the short-run. Such an orientation will result in a significant decline in volunteer adoption of erosion control practices because most soil conservation practices have been shown to produce relatively low returns on investment (Ervin and Washburn 1981; Mueller et al. 1985; Napier and Forster 1982; Swanson et al. 1986). Returns on investments, when they do occur, are often not received until future years, and a large proportion of land operators do not have the ability to wait so long to receive a return.

Even though financial stress being experienced by many land operators is certain to impede volunteer adoption of soil erosion control practices, the CRP has the potential to off-set some of these negative impacts. It is highly likely that many land operators will be attracted to participate in the CRP by the guaranteed rents attached to participation (Agricultural Outlook 1986). It has been repeatedly demonstrated that farmers have adopted soil conservation practices when economic incentives have been offered as inducements (Bouwes and Lovejoy, 1980; Lovejoy et al. 1980; Napier and Forster, 1982).

The CRP requires the development of a conservation plan before farmers are permitted to enroll highly erosive land. Compliance with the CRP contractual agreements will result in the retirement of highly erosive enrolled land for a period of time and the use of soil conservation practices when it is returned to production or the land operator will be subject to penalty. The economic incentives associated with the CRP will attract many participants who would not have otherwise incorporated conservation practices into their farming.

While the conservation components of the 1985 FSA have the potential to increase farm income for land owners, they also may create problems for land operators who are renters. This is a potential adverse impact that must be recognized. In 1986, the bid price of land included in the CRP in certain areas of the country was almost one third of the total purchase price of the land (Agricultural Outlook 1986). Such rental levels will maintain the income of land owners, but will make it difficult for renters to compete in the land market.

Such high rents relative to purchase price also encourage investment by outside people, thereby exacerbating the socioeconomic impacts on rural community groups as previously noted. If high rents are maintained by the CRP, many farmers and ranchers who operate rental land will be forced to leave agriculture for a period of time.

Another potential problem associated with the CRP is the inability of program participants to sell encumbered land unless new buyers agree to fulfill contractual agreements. Long-term CRP agreements provide participants with guaranteed payments, but they also may prevent financially stressed land operators from selling their land if such a need arises. Under present regulations, if a financially stressed farmer elects to sell his/her land to pay debtors while enrolled in the CRP, the new owner must agree to assume the responsibility for fulfilling the contract or the original owner will be required to return CRP payments received to the government. Such regulations are essential to ensure that contractual agreements are met, but they pose a potential problem for financially stressed land operators enrolled in the CRP.

Future Policy Considerations

While the conservation components of the 1985 FSA have the potential to significantly affect land management practices in the U.S., there is a major threat to their potential effectiveness. The threat is in the form of political pressure to change the objectives of the conservation programs. The conservation components of

the FSA were primarily designed as conservation programs with secondary impacts on commodity prices and maintenance of farm income. The financial situation in agriculture combined with national sentiments to reduce or eliminate commodity programs will create considerable agitation on the part of agricultural interests to find substitutes for the farm income maintenance programs. The conservation components of the FSA will undoubtedly be examined as replacements for commodity programs eliminated. Such a strategy, in my opinion, would be counter productive to national environmental goals and would not significantly reduce the impact of the farm financial crisis for farmers and ranchers most significantly affected.

It is quite possible that some narrowly focused agricultural interests will perceive CRP payments as having the potential to mitigate the loss of traditional farm income maintenance programs. Such perceptions are probably unrealistic because the magnitude of the farm financial problem is beyond the scope of the rents received for highly erosive land. The CRP will likely have only a minor effect at the national level in reducing the farm financial crisis, but should have a slightly higher influence in areas where there are many financially stressed farmers and ranchers operating marginal farm land. The CRP funds will have the effect of transfer payments in such communities.

Since CRP funding is targeted to highly erosive lands, it is unlikely that the limited funding will significantly reduce the high debt ratios of financially stressed land operators. The young, middle class farmers and ranchers, who are experiencing the most financial stress are not more heavily involved in the CRP than those who are financially stable, at least as it is presently organized.

Attempts to expand the CRP qualifications so that every financially stressed farmer and rancher can participate would defeat the purpose of removing highly erosive land from crop production. While attempts to make everyone eligible for the CRP may be politically expedient, targeting of limited resources can be defended from a variety of perspectives (Napier 1987). Economic and human resources are insufficient to remove all highly erodible land from crop production. If the additional objective of mitigating financial stress in agriculture is added to the CRP, the program simply will not achieve any of its specific goals.

Another reason for not changing existing goals and objectives of the conservation components of the 1985 FSA is the potential loss of political support of nonagricultural interests. If narrowly focused agricultural interests should be successful in changing the emphasis of these components from a program primarily designed to reduce soil erosion to an income enhancement program for land operators, it is quite possible that present nonfarm allies will become alienated.

Nonfarm allies are essential, if agriculture is to remain a viable industry in this society. Several interest groups were extremely important in the development and passage of the conservation components of the FSA and their goodwill must be maintained. Maximization of short-term benefits by narrowly focused agricultural interests could result in a significant loss of a political support base, thereby negatively affecting agricultural and natural resource policies for decades.

The policy decisions made in the near future concerning the conservation components of the FSA are extremely important in terms of the political future of agriculture and natural resource interests in this society. It is surely possible that political decisionmakers will approach the resolution of the farm financial situation from a politically expedient short-term perspective. If such an approach is used, the conservation components of the FSA may become nothing more than another farm income maintenance program. As a consequence, it would be highly unlikely that reduction of soil erosion or the reduction of financial stress in agriculture would be accomplished. The potential social impact of such a situation is the alienation of several significant nonagricultural publics that are significant actors in the policy arena. The loss of their political support would affect the allocation of resources to agricultural and rural development problems for a long period of time. Of all the possible adverse outcomes of the CRP, this would probably be the most costly in the long-run.

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Policy Questions from CRP in the Midwest

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Abstract.--Environmental policy development is both inherently difficult and difficult to model. The 1985 Food Security Act forced conservation policies to be developed and implemented in a short time and with little information. There are many areas where the Conservation Reserve Program (CRP) needs attention. CRP will substantially impact the Nation's pattern of cropland use, but it is not a long term solution to soil erosion problems. However, as problematic as the Conservation Title is, it is a big step in the right direction. While it is premature to draw profound conclusions, there is time for data collection, analysis, and course correction.

We are now in the early, formative years of a 10-year Conservation Reserve Program (CRP). Other papers in this Proceedings have addressed program specifics; however, this presentation deals with policy. Four issues are addressed; (1) policy in the 1985 Food Security Act, (2) environmental policy in a philosophical context, (3) policy issues regarding CRP implementation in the upper Midwest, (4) and a concluding section.

This paper relies on three sources. First is a series of papers presented at a NCR-111 workshop in June 1987.[2] Second, the published literature is beginning to grow with papers/reports on various aspects of the Conservation Title. They are cited as appropriate. Finally, I draw on my experiences observing policymaking at local, state, and federal levels, which causes me to be a bit skeptical and pragmatic.

Farm Bill Conservation Policy

The Conservation Title of the 1985 Food Security Act (FSA), some would say, represents the federal government's policy on conservation related to agricultural production. Federal legislation in general is purposefully vague and the CRP is no exception.

While provisions, such as sodbuster and cross-compliance, have only recently been specifically articulated, economists, and others (e.g., range managers), have espoused such provisions for some time. The Congressional Office of Technology Assessment (1985), along with Congressional committee and staffers, helped Congress frame many of these provisions by providing the "objective information" of the public-choice policy model.

The FSA is an omnibus piece of legislation that provides a framework within which the Secretary of Agriculture is to administer its various programs. The Act gives the Secretary considerable discretion in implementing its provisions. A wholesale lack of information led most in Congress to the familiar cop out: "Let the Secretary decide." Bills are deliberately written to allow this discretion so lawmakers and the administration are not locked in to situations they may not foresee. It allows them flexibility to modify their policies or interpret acts to suit changing political climates. While legislators prefer vagueness to clarity, regulators, the federal agencies, need a certain degree of specificity and guidance to implement programs. Though flexibility should be a dominant characteristic of policy, it requires a clear statement of goals (Henderson et al. 1987).

Federal regulations that appear to be extremely detailed, demanding, and intrusive, often end up looking like paper tigers when it comes time for implementation and enforcement. While the general objectives of a program may be popular, soil conservation for example, the threat or imposition of sanctions is not. These and similar ideas about environmental policy are developed by Beam (1983).

Thus, a hard and fast conservation policy is not set in the FSA, but rather a framework is provided, within which the administration can attempt to articulate and implement its policies.

The stated purpose of the FSA (in report language) is to provide, as far as it can be done in legislation of this kind, the basis

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[2]North Central Regional Committee 111, Natural Resource Use and Environmental Policy Committee, was established in 1980 and is comprised of members from land grant universities in Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, Wisconsin, and the USDA. The members' universities and the Farm Foundation sponsored the workshop entitled, "The Conservation Title: What Have We Learned?" Six papers were presented on an overview, public education aspects, land owner participation, related state efforts, commodity specific effects, and policy challenges.

for an economic climate in which efficient American family farmers can survive the grim squeeze that has already driven too many of them to or close to the brink of ruin (99th Congress 1985).

While this sounds more like a social program than a conservation program, the Act does include the Conservation Title, not as a primary purpose, but rather as a consolation to the environmental community. Amidst growing public skepticism, and with an administration ideologically committed to removing government from the marketplace, agricultural interests had little choice but to compromise and give environmentalists room to push their agendas. PIK payments had caught the public's attention when North Dakota wheat farmers, California cotton farmers, and southern rice farmers received large government payments to not farm. Also, urban congressmen began to see the rising costs of the farm program competing for limited federal funds, and all citizens have begun to take note of off-site consequences of soil erosion. CRP, though, would achieve objectives of agriculture, the environmental community (Kovan et al. 1987), and hopefully deficit reduction by reducing commodity payments.

Environmental Policy

Policy is a slippery concept that appears easy to define until one tries to do it. Policy is an individual or group conclusion as to the role of government with respect to a particular problem or circumstance; in this case, agriculture and conservation. The public-policy decision process has been thoroughly explored. Many models drawn from varying perspectives and philosophical predilections have been developed.[3] Barrows and Carriker (1987) discussed the role of politics and the market with respect to how natural resources are allocated. They concluded that from a national perspective, there are few constraints on agricultural production; however, agriculture's future in specific areas is subject to many forces and interests.

The popular, yet naive, public-interest model, where technical experts provide objective information to decision makers who decide in the public interest, is as far from realistic policymaking. Randall's (1987) diffuse model of public-policy decisionmaking more aptly describes environmental policymaking. Four basic elements of Randall's model are:

* Conflicts may be resolved in many arenas (legislative, executive, judicial, and the marketplace).
* Individuals have diverse endowments and seek to maximize their own personal well-being, employing these endowments in the various policy arenas.
* Public decisionmakers also pursue their own self-interest, which may or may not coincide with institutional objectives.
* Public decisions are often not final (except for the irreversible destruction of some natural systems).

The diffuse model supports the contention that most policies evolve or just happen. Their development does not follow any particular, well-anticipated path. This seems especially true of policies coming out of Washington, D.C., where pluralism, reelection, and political self-interest drive many public policymakers. "The translation of values [public or the decisionmaker's] into public policy is what politics is about." (Knutsen et al. 1983)

Policies are necessary when science/economics cannot provide objective solutions to moral or value issues. Normative conclusions cannot be derived from positive premises alone (Randall 1987). Policy connotes decision and action by and for society. The question we should ask today is, "Who is society?"

Is it the Oklahoma panhandle? The upper Midwest? Or cattlemen? Of course not, but those are the special interests we hear about with respect to FSA sanctions. Hence, federal policy becomes special interest policy when it affects you, but what happens to Society's interests?

Upper Midwest CRP

Over one-third of 350 million acres of highly erodible cropland in the U.S. is in the Midwest. As of the last signup, CRP enrollment in Minnesota exceeded 1.5 million acres at a bid of \$55.89 per acre; in Montana it exceeded 1.7 million acres (at \$37.31), in North Dakota about 1.5 million acres (at \$38.15), and in South Dakota more than 800,000 ac. are enrolled (at \$39.08). These four states represent almost one-fourth (24 percent) of all lands enrolled thus far. In fact, total CRP acreage would equal the area of 25 counties in North Dakota, about half of that state. Some farm-level examples will help to highlight issues and questions.

A South Dakota farmer who is retired and never farmed under any farm program, put all of his land into the program at \$27.87 an acre. He stated that the CRP is going to catch on like wildfire, and will be the only way to make any money. He estimated that 80% of the farmers can't do near as well on their own (Crumrine 1987). Does this sound like a socially efficient program?

A farmer from Perham, Minnesota enrolled 30 acres at \$42.50 per acre and got more than he would have for rent. There are widespread examples of CRP payments exceeding local land rents and, while there may be valid economic arguments for this, it nevertheless puts pressure on local rental markets.

A Streeter, North Dakota, farmer who enrolled 465 acres at \$30 an acre, said, "I'm of retirement age. Anytime I can get my land into a reserve program and get income, it suits me." Cash rent runs \$15 to \$20 per acre in his county.

A Canby, Minnesota, farmer observed that the CRP looks good for farmers, but not for business. "It will definitely affect Canby, ...Some businesses are quite upset." The \$70 the government offers for reserve land looks awfully good beside the \$40 an acre that cash rent brings.

[3]See, for example, Knutson et al. (1983) regarding agricultural and food policy and Randall (1987) regarding natural resource policy.

Some think the program is not fair, because in some areas the enrolled land is used for hunting. For example, a Barnesville, Minnesota, farmer placed 800 acres into CRP and is now operating a hunting preserve at $12 per pheasant (McEwen 1987). South Dakota farmers learned the value of hunting leases during the PIK years. Of course, Texas land owners have capitalized on hunting related income for years.

In Michigan, farmers were found to not understand the provisions of the conservation title (Purvis and Sorenson 1987). The most popular reasons for enrolling were to cover land payments, to have a guaranteed income, and to make good use of land that is not profitable to farm in today's market conditions. Problems with the CRP included inadequate staffing of local agency offices, extensive or complicated rules (although CRP was the best understood provision in the conservation title), unclear government directives, changing rules, and a perception that the program rewarded poor managers with no consideration for farmers who have used their land properly. This is not unique to Michigan, however.

Reinvest in Minnesota (RIM) (Payer and Hicks 1987) has a land conservation goal to encourage retiring marginal agricultural lands. The long range goal is to retire about 2.3 million acres to provide wildlife habitat and prevent soil erosion and water pollution. Payments in RIM were originally tied to CRP, but this resulted in large windfalls to landowners. Minnesota is now considering annual adjustment of rental rates and has moved from a 10-year to a 20-year contract. Lands eligible for RIM are selected based on low agricultural productivity and high erodibility. Minnesota's goal is to retire unproductive land, not to reduce federal commodity payments. RIM was sold to the Minnesota Legislature and the public as a wildlife enhancement program, but it also provides lump sum payments seen as a help to distressed farmers.

Policy Questions

There is a broad range of policy questions depending on one's perspective. But, since CRP is a federal program, this paper addresses policy from a federal perspective. Three federal policy perspectives with respect to CRP are by the administration, Congress, and the agencies.

The administration, or the executive branch, is concerned with the federal budget, which translates into ensuring there are limits on programs that cost federal dollars. Secondly, the current administration is concerned with getting the government out of agriculture. Other than these two broad policy prescriptions, the executive branch is content to let others concern themselves with details of implementation of a program that Congress initiated.

Congress, on the other hand, is concerned with getting reelected and, because of this, needs to listen to its constituents. Congress is thus concerned about the family farm, cattlemen, ornamental tree growers, the environment, and a plethora of other special interests. Congress is generally not concerned with the federal budget, unless it means having to raise taxes.

The agencies' (part of the executive branch) job is to implement laws that Congress enacts, within the policy guidelines of the administration. Federal agencies are mostly mission postured. Because of this mission orientation, different agencies sometimes work at cross purposes--one hindering or undoing the work of the other.

Agencies are concerned, then, with implementation policies--how to implement the provisions of the Conservation Title while staying within the administration's policy guidelines, yet while meeting the expectations of Congress. Agencies are concerned with the administration's wishes, but are also cognizant of Congressional budget power. Since much was left to the Secretary's discretion in the Conservation Title, many implementation questions needed/need to be answered (Dicks and Reichelderfer 1987):

Which land is eligible for CRP?
...on a regional basis?
...by crop history?
...based on erodibility?
...consistent with other FSA provisions?

How large should the bid pool be?
...regional?
...national?

What should be the bid selection criteria?
...minimize CRP outlays?
...maximize erosion reduction?
...minimize government commodity payments?
...minimize net cost per ton of erosion?

What uses should be allowed on CRP lands?
...concern with social efficiency?
...concern with effect on special interests?
...concern with year 11?

What will be the effect on commodity prices?

How will provisions be enforced?
...creative farm ownership?
...bad public image?

Along with this list of questions, as well as many others, come several concerns at the local and state level. For example, the effect on land rents has caused some concern because it disrupts local markets. In Minnesota, the CRP payment to rent ratio is well over 1.0.

Discussed elsewhere in these Proceedings is the effect on local economies. The first question should be, "Should the federal government be concerned about the economies of places or of people?" Obviously "they" were concerned about places, since one CRP provision was that no more than 25 percent of the cropland in a single county may be enrolled. Hence, this limit has been exceeded in more than 50 counties.

Is it an objective of the FSA to preserve "living museums" in the form of small towns across the Great Plains? If hardware and grocery stores depend on socially damaging uses of natural resources to survive, shouldn't those resources be released to be put to better use elsewhere in the economy? Finally, the millions

of dollars in CRP payments injected into rural economies is good for business, but out of whose pockets do these millions come from? Is more damage being done in other sectors of the economy than would have existed in lieu of these payments to agriculture?

Local governments that rely on property taxes for revenue may need to adjust to CRP. In many areas the "agricultural value" of land is its taxable value. CRP land has no agricultural value for 10 years.

How will agencies accustomed to being friends of agriculture adjust to being enforcers of some CRP provisions that are unpopular? Further, the Soil Conservation Service will need an additional 3,000 employees to fulfill this new role of enforcer.

Conclusions

Each of the four elements in Randall's (1987) model of policymaking can be seen at work in development and implementation of CRP policy. It has been neither smooth nor easy to get here, and much remains to be done. Broad legislation leaves programs dependent upon implementation policy.

Policy means choices. Not everyone is going to be happy. Most farmers are happy with CRP in principle; poor managers are happiest. Environmentalists are happy, for now. Farm input suppliers are not happy, except for grass seed dealers. Taxpayers are generally not well enough informed.

CRP will have a substantial impact on the Nation's pattern of cropland use; but it is neither a long term solution nor a stable basis for a conservation program, especially as long as we have a two- and six-year Congress. Further, a single, narrowly defined, national soil conservation policy does not work, but leads to resource use inefficiencies.

Market prices will be an important variable in what happens in year 11; however it is still too early to draw profound conclusions. We need to watch closely, maintain good records of what happens and, hopefully, there will be opportunities to fine tune CRP.

Some say we moved too fast on this one--before we had adequate information. As problematic as the Conservation Title is, it is a big step in the right direction. Let's make the most of this opportunity.

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The Role of Wildlife as an Economic Input into a Farming or Ranching Operation

Fred C. Bryant and Loren M. Smith[1]

Abstract.--The economic role of wildlife in Texas' farming and ranching operations varies from being the most important product to providing only supplemental income. The Conservation Reserve Program (CRP) offers High Plains and Rolling Plains farmers and ranchers an opportunity to enhance wildlife on their land and supplement their income. Management alternatives are offered to improve upland game and big game habitat under CRP guidelines.

"Like finding a bird nest on the ground" is the colloquial phrase generally used to describe stumbling into that golden opportunity. On the High and Rolling Plains of Texas, the Conservation Reserve Program (CRP) is the "bird nest" which can literally be feathered by ring-necked pheasants *(Phasianus colchicus)*, quail *(Callipepla squamata* and *Colinus virginianus)*, waterfowl, and lesser prairie chickens *(Tympanuchus pallidicinctus)*, all species representing potential economic returns to a sagging agricultural industry. What other program could offer a businessman cash for purposely not manufacturing one product, and provide potential revenue for another product whose output increases with only minor adjustments and inputs? This is how we view the economic role of wildlife in the CRP -- as an opportunity for farmers and ranchers to enhance wildlife populations on their land, and possibly their income.

Landowners in Texas, 98% of which is privately owned, have for some time recognized the importance of wildlife [primarily deer (*Odocoileus* spp.), quail, and wild turkey *(Meleagris gallopavo)*] in their farming and ranching operations. Even in the depressed economy today, landowners sell trespass rights to hunting sportsmen for as little as $0.50/ac to as high as $12-$15/ac. In some examples, the role of wildlife as an economic input has long since exceeded the net revenue generated by livestock or other cash crops. And for those who fear these landowners only exploit the wildlife resource, take heart, because many are plowing money right back into habitat enhancement programs. Some ranches are even beginning to hire full-time wildlife biologists along with, or instead of, ranch managers. To date, however, this is the exception and not the rule. In most instances, revenues from wildlife still just supplement farm and ranch incomes, a situation that will probably remain for some time to come.

The focus of this paper centers on the High and Rolling Plains of Texas, a region rich in farming and ranching heritage. On the High Plains, a semi-arid land of sub-irrigation and level topography, farming has provided the economic base of rural communities for the past 60 years, and should continue to do so for years to come. On the Rolling Plains, livestock play a more important role, but the area still is heavily farmed. The CRP offers farmers and ranchers a chance to set aside part of their farmed acreage, and do something for the wildlife resource and potentially supplement their income from hunting lease fees. Thus, the primary objective in this paper is to offer management alternatives to enhance wildlife under the CRP and to report a range of economic returns for the region described above.

Upland Game

Ring-necked Pheasants

On the High and Rolling Plains the CRP probably has the potential to benefit upland game species more than any other wildlife group. This is particularly true for ring-necked pheasants. The range of the ring-necked pheasant in west Texas is primarily restricted to the High Plains, which, as mentioned above, is also one of the most intensively cultivated regions in North America (Bolen 1982). Therefore, the CRP has the potential to greatly improve habitat in this region. Guthery et al. (1980) noted that, because of intensive farming, there are deficiencies

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in nesting and wintering cover for pheasants. Travel lanes are also limiting because there are few permanent idle areas and roadside vegetation is sparse due to clean farming techniques.

Currently, playas (shallow windblown depressions that retain water) form the most important nesting and wintering habitat for pheasants in the region. These playas produce 40% of the pheasant crop, yet account for less than 2% of the land area (Guthery et al. 1984). Nonetheless, playas are frequently burned and grazed by cattle which decreases their carrying capacity for pheasants during winter (Guthery et al. 1984). In addition, because heavy precipitation commonly occurs during peak nesting in May and June, nest losses from flooding of playa basins can be high. Therefore, the CRP can benefit pheasants by compensating for these most critical habitat needs.

Dense and tall grasses, such as switchgrass *(Panicum virgatum)*, with a mixture of forbs will create good winter and nesting cover. Forbs such as sweetclover (*Melilotus* spp.) and alfalfa are often recommended. After substantial litter accumulation in 4 to 5 years, burning of grass cover in late winter will improve nesting conditions (Schramm et al. 1987). Fires in spring are detrimental to nesting.

Food is generally not a limiting factor in most of the region because of the prevalence of corn and sorghum crops. If existing dense vegetation in a playa can be contracted under CRP as "permanent vegetative cover already established" pheasant habitat will be improved by preventing grazing and other potential alterations. Playas receiving seasonal water can have dense stands of cattail (*Typha* spp.), smartweed (*Polygonum* spp.), and summer cypress *(Kochia scoparia)*, which provide excellent habitat (Whiteside and Guthery 1983).

Establishment of woody vegetation by creating windbreaks or scattered clumps will further improve cover by meeting needs for summer loafing sites and protection from severe winter weather. A playa wintering area can be used by pheasants in a 0.7 mi radius (Whiteside and Guthery 1983).

A management plan following the above recommendation will increase pheasant numbers. The economic return from these practices to landowners on the Southern High Plains can be substantial and is only now beginning to reach its full potential. Although lease fees paid to landowners for pheasant hunting are known, the economic benefits to local communities from increased restaurant and motel use, for example, are not available. Community returns are thought to be significant however, because of the great influx of hunters.

Guthery et al. (1984) noted that, for those areas with the best pheasant populations, lease fees were $75/hunter for opening weekend, $50/hunter for the second weekend, and $25/hunter for the third weekend. Guthery et al. also listed potential lease fees for a section (640 ac.) of land that had varying habitat value. In areas of the High Plains with the highest pheasant populations, lease fees ranged from $600 to $4,500/section depending on the crops and winter cover available. Areas with lower pheasant populations range from $200 to $1,700/section.

Quail and Mourning Doves

Northern bobwhites and scaled quail occur on the High and Rolling Plains. Most habitat management centers around production of bobwhites because they are preferred more by hunters. Neither quail species occurs in high population levels where the area has been intensively cultivated. Therefore, quail populations are higher on the Rolling Plains than the High Plains. Cover planted for quail should not be as tall as that planted for pheasants, i.e., not exceeding 2 ft. in height. This should be planted in small blocks or strips because large dense stands of grass restrict optimum bobwhite production.

Planting of woody vegetation will benefit bobwhites (10-25% cover), but scaled quail require much less woody cover (Schramm et al. 1987). If shorter grasses planted for quail, such as sideoats grama *(Bouteloua curtipendula)* or little bluestem *(Schizachyrium scoparium)*, seed-producing forbs [i.e., Illinois bundleflower *(Desmanthus illinoensis)*, Maximillian sunflower *(Helianthus maximiliani)*, partridge pea *(Canavalia fasciculata)*] should be mixed in with the grass, to enhance quail habitat because food is often limiting (Schramm et al. 1987). Also, quail numbers can be increased through the recently approved "annual wildlife food plots" conservation practice used to improve the food base in large stands of grass. Although food plot establishment is not cost shared, annual rental payments are still provided by the government. Food plots should be long and narrow, situated perpendicular to the prevailing winds, and occupy less than 10% of the total acreage covered under the CRP agreement. Sunflowers or grain sorghum serve as good food plots. Prescribed burning (every 3-5 years) of grass stands in late winter is used to maintain optimum quail habitat by eliminating undesirable litter accumulations (Schramm et al. 1987).

Mourning doves *(Zenaida macroura)* will also benefit from annual wildlife food plots if there is some bare ground between rows to allow doves to feed. Nesting can be improved by providing windbreaks, shrubs, and trees. Shallow water areas as permitted under CRP, will also attract doves.

Most dove leases are on a day-lease basis in the Texas High and Rolling Plains. For the first few weeks of the season a fee of $25/hunter/day is common. After the first few weeks prices drop to $5-$20/hunter/day. Quail leases are generally conducted on the basis of larger land areas and, therefore, prices are charged on a per unit area basis. Average lease prices range from $0.50 to $2.50/ac. Areas that practice more intensive habitat management may receive more than $3/ac.

Lesser Prairie Chickens

Lesser prairie chickens have a very restricted range in west Texas; primarily in the Panhandle along the border with Oklahoma and on the western border with New Mexico (Jackson and DeArment 1963). Prairie chickens occupy those sandy soil types dominated by shinnery oak *(Quercus havardii)* and sand sagebrush *(Artemisia filifolia)*. Previously cultivated areas adja-

cent to current prairie chicken range that enter into CRP agreements should be planted to those native grasses that are adapted to sandy soils such as switchgrass, little bluestem, or sand bluestem *(Andropogon hallii)*. A mixture of forbs, such as Illinois bundleflower, partridge pea, or sweetclover, may improve food conditions (Schramm et al. 1987). Small annual food plots of grain sorghum may also elevate the food base.

Because the prairie chicken hunting season is only 2 days in Texas, the economic potential for hunting lease rights is low. Landowners commonly receive $25-$50/hunter/day for prairie chicken hunting. Prairie chickens often serve as an enticement on larger land leases for other wildlife, such as quail, and can improve the overall lease price.

Waterfowl

Over 1 million waterfowl may winter on the High and Rolling Plains (Buller 1964). Most waterfowl are concentrated on the 18,000 playa lakes in the region (Guthery and Bryant 1982); therefore, management for waterfowl is essentially management of playas. Because of fluctuating water levels, most playas contain vegetation that waterfowl prefer, e.g. smartweeds, cattail, barnyard grass *(Echinochloa crusgali)*, and, hence, the lower basin may be contracted under "permanent vegetation already established." This natural vegetation will generally attract waterfowl and planting in the lower portion of the playa basin is not recommended. Where water is much more ephemeral, it may be possible to provide a more permanent source of water for waterfowl under the conservation practice, "shallow water areas for wildlife." Although not thought of as an important breeding area, the playas can produce large numbers of birds (Rhodes 1978). To promote waterfowl nesting, it is recommended that grass-forb mixtures, as recommended for pheasants, be planted on the areas immediately surrounding playas.

Although the playas have vast numbers of waterfowl, the interest in waterfowl hunting in this part of Texas is low. Waterfowl hunting traditions have not become well established in the High Plains relative to the coastal and eastern areas of the state. Therefore, very few waterfowl leases presently exist and the economic potential is low compared to these other areas. Most hunting rights that are leased are done on a daily basis for only $10-$20/hunter. Leasing for waterfowl hunting rights, however, may be increasing as evidenced by hunter-guiding activity in the region.

Big Game

Several species of big game occur on the High and Rolling Plains. On the High Plains, mule deer *(Odocoileus hemionus)* and white-tailed deer *(O. virginianus)* are found along creeks, rivers, and dry arroyos, and along the escarpment between the High and Rolling Plains. Densities usually are low compared with other regions of Texas. Pronghorn *(Antilocapra americana)* occur in small herds all across the High Plains where intensive farming is absent. White-tailed deer are the dominant big game species of the Rolling Plains and can occur in fairly large numbers, but mule deer and pronghorn populations are spotty.

In all habitats across the High and Rolling Plains, brush cover probably limits distribution of deer and a weak food base acts to limit population size (Sowell et al. 1985), along with cover.

If CRP farmland is adjacent to or interspersed with known deer or pronghorn habitat, it could be planted to enhance big game habitat under CRP guidelines. Because food is limiting, plantings should be directed at supplementing seasonal nutrition needs. Sweet clover, sanfoin, alfalfa, Illinois bundleflower, and Engelman Daisy *(Engelmannia pinnatifida)* supplement spring and summer nutrition of big game. Because annual plantings are now allowable under the CRP (10% of total area only), grain sorghum can be planted each spring to enhance late summer/fall nutrition, while winter wheat and triticale could be planted in late summer each year to boost winter nutrition, (Wiggers et al. 1984, Bryant and Morrison 1985). Several shrubs also are available to stabilize the annual food base (Schramm et al. 1987).

Deer leases currently bring $2-$4/ac. in the Rolling Plains. Where populations are sparse in the High Plains, package hunts or buck permits are sold. Package hunts for mule deer currently range from $500 to $1,500; pronghorn permits bring $300-$600.

Summary and Research Needs

The potential economic return for landowners managing for wildlife on the High Plains is probably highest for ring-necked pheasants. On the Rolling Plains, quail and big game should receive high priorities for management. At present, the economic return relative to the CRP investment is lower for waterfowl and lesser prairie chickens.

Research is needed to determine the importance of recreational hunting on the local economy as a whole and not merely landowner benefits. Mitchell and Evans discuss this and other research needs in this Proceedings.

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The Role of the Conservation Reserve Program in Relation to Wildlife Enhancement, Wetlands and Adjacent Habitats in the Northern Great Plains

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Abstract.–The Conservation Reserve Program (CRP) will enhance wildlife populations of the Northern Great Plains by providing acreage increases in both quality and quantity of grassland and woodland habitats. One of the greatest benefits of the CRP will be the addition of grasslands in conjunction with the U.S. Fish and Wildlife Service's wetlands easement program on private lands. Recommendations are provided on the establishment, maintenance, and post-contract use of CRP grasslands.

For approximately the past 4,000 years the Northern Great Plains region has been dominated with perennial grasslands of one type or another complemented by woody draws, riverine woodlands, patches of shrublands, and millions of wetlands, often described as hydric grasslands. In less than 150 years, many of the natural plant communities in this region have been converted into croplands or other socio-economic uses to provide food, fiber, shelter, and transportation rights-of-way. Through time, thousands of wildlife species evolved and adapted to the perennial grassland habitats of the Northern Plains, but today the remaining wildlife survive in ever decreasing and disjunct habitats of perennial grassland.

It is no surprise then, that natural resource managers join with agriculturalists to support and provide guidelines for implementing a national agricultural program that returns large acreages of annual croplands back into perennial grasslands.

It would take several volumes to describe all of the assets and deficits of the Conservation Reserve Program (CRP) of the Food Security Act of 1985 to prairie wildlife in the Northern Plains region. For the purposes of this paper, attention is focused on the value of CRP grasslands in relation to wetlands and their associated wildlife, primarily migratory birds. Recommendations for the CRP acreages, including the post-contract period, are provided.

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WETLANDS PERSPECTIVE

Interior fresh-water wetlands in the Northern Plains provide many ecological and socio-economic values to the citizens of North America. Wetlands can enhance local and regional water quality and supply by acting as surplus nutrient traps, chemical sinks, groundwater recharge areas, flood water retention basins, livestock watering holes, and occasionally, reservoirs for irrigation water. Wetlands can also enhance the quality of our personal lives by providing us with surface water space, fish, wildlife, and the beauty of aquatic vegetation.

Wetlands in the Northern Plains region have been converted or lost to other uses at an alarming rate during the past 150 years (Shaw and Fredine 1956). Tiner (1984) estimated that less than 50% of the original wetlands in the region remain today. The combination of less perennial grassland and wetland areas has been attributed as, possibly, the most important factor contributing to the decline in continental waterfowl populations. The majority of the wetlands in the glaciated prairie pothole region of the Northern Plains occur east or north of the Missouri River in the Dakotas and Montana, in western Minnesota and Iowa, and in the rainwater basin area of Nebraska, where intensive annual

tillage occurs over broad areas. As a result, many of the remaining wetlands are left isolated by a considerable distance from any type of perennial grassland habitat, except for narrow strips of highway rights-of-way.

WETLANDS VALUES TO WILDLIFE

Prairie wetlands have long been valued as a critical habitat for migratory birds, fish, and furbearers in North America. Some studies have also identified their importance to other game species. In the upper midwest, wetlands with dense stands of emergent vegetation have been found to be an important winter covert for white-tailed deer *(Odocoileus virginianus)* (Rongstad and Tester 1969), (Sparrowe and Springer 1970). Wetlands have also been found to be a very important winter covert for ring-necked pheasants *(Phasianus colchicus)* in Iowa (Green 1938, McClure 1948, Nelson 1950, Lyon 1954, Sather-Blair and Linder 1980). Especially in drier years, wetlands also have been rated as a valuable source of cover and space for pheasant nesting and reproduction (Baxter 1972, Kuck et al. 1970).

All waterfowl species use wetlands at one time or another for nesting, breeding, feeding, resting, or as migration staging areas. Some waterfowl, e.g. canvasback *(Athytha valisineria)*, are totally dependent on wetlands for all of their life cycle needs, whereas others, e.g. mallards *(Anas platyrhynchos)*, are only partially dependent on wetlands for their life cycle needs; i.e., mallards, often nest and feed in either uplands or wetlands.

Less understood is the critical nature of prairie wetlands isolation to the migration patterns and survival of waterfowl, smaller passerine species and shorebirds. Banding studies have shown that many bird species follow traditional migration routes from year to year. This poses several important ecological questions, yet unanswered; e.g., do migratory passerines need a continuum of fairly closely associated wetlands to maintain or restore their energy fat reserves along their migration routes? Do migratory passerine species need wetlands in combination with adjacent grassland areas to provide part or all of their daily needs during the reproduction period?

The answers to these and other questions are further confounded by the fact that prairie wetlands are highly variable in size, depth, water chemistry quality, vegetation composition, location, and basin land use. These unknowns have made wetland preservation programs very complex and, so far, inadequate relative to the continuing wetland drainage rates and losses. This brings us to an all important question: "How can the CRP enhance wildlife and wildlife habitats in the Northern Plains?"

WETLANDS PRESERVATION

In the early 1900's it became apparent that wetlands preservation was necessary in order to maintain waterfowl and other wetland wildlife population levels. Enactment of the Migratory Bird Hunting Stamp (duck stamp) Act in 1934 provided some funds for wetland protection. Many of the National Wildlife Refuges in the Northern Plains were purchased during the 1930's. However, wetland drainage gained momentum during World War II and in the following years. Wetlands protection continued at a slower rate than the drainage acceleration. In 1958 the Migratory Bird Hunting Stamp Act was amended to enable the U.S. Fish and Wildlife Service (FWS) to begin more intensive wetland preservation via purchase and easement options in the prairie pothole region of North and South Dakota, Minnesota, Montana and Nebraska.

In 1961 the FWS Small Wetlands Acquisition Program (SWAP) was enhanced with the passage of the 1961 Wetland Loan Act. The Loan Act has been extended three times since 1968 and continues today. Since the beginning of SWAP, the FWS has acquired fee title to approximately 1/2 million acres of waterfowl habitat and has protected approximately 1.2 million wetland acres with easements, mainly with perpetual contracts, in the glaciated prairie pothole region of the Northern Plains.

The FWS's fee title acquisitions, commonly referred to as Waterfowl Production Areas (WPA's) contain both uplands and wetlands, whereas, the easements, with few exceptions, protect only wetlands. According to unpublished reports, approximately 18,000 individual basins totalling about 256,000 wetland acres were protected on refuges and WPA's in the five-state area. In comparison, if it is assumed that the average wetland equals one acre in size, about one million wetlands have been protected with FWS easements. In addition to the FWS's wetland preservation effort, all states in the prairie pothole region of the Northern Plains also have purchased some wetlands, and the USDA has sponsored the Water Bank Program which protects wetlands and provides adjacent herbaceous cover during 10-year contracts.

WILDLIFE BENEFITS EXPECTED FROM THE CRP DURING THE CONTRACT PERIOD

CRP Acreage in the Northern Great Plains

As of August 1987, approximately 5 million acres of perennial grasslands and between 3,000-4,000 ac. of trees have been contracted for establishment in the Northern Plains states of Nebraska, North Dakota, South Dakota and Montana. Some CRP grassland acres are expected to be established in nearly every county within the prairie pothole region of the Northern Plains. This type of geographic distribution of CRP grassland will ensure shorter distances among parcels of undisturbed habitat. Some counties already have more than 200 CRP contracts totalling more than 50,000 ac. This density and total area of grassland habitat in a county has the potential to greatly enhance wildlife production on a local basis and, to a lesser degree, on a flyway and national basis since migratory species will benefit.

Wildlife Benefits From CRP Trees

Wildlife, soil erosion, and water quality benefits from CRP lands are anticipated beginning with the first year of complete growth. However, benefits from tree plantings will take longer to develop than grass plantings because of their slower growth and maturity rate. Establishment of woody plantings on CRP lands will provide long-term ($\geq$ 20 years) benefits to several wildlife species in the Northern Plains. Such woody plantings provide winter cover for white-tailed deer, ring-necked pheasants, gray partridge *(Perdix perdix)*, and sharp-tailed grouse *(Tympanuchus phasianellus)* (Henderson 1984). They also provide year-long habitat for squirrels, cottontail rabbits, and white-tailed jackrabbits and summer nesting habitat for mourning doves *(Zenaida macroura)* and several species of passerines.

Wildlife Benefits Expected From CRP Grasslands

From 50% to 85% of the Northern Plains region is annually tilled for the production of grain and oil seed crops (Higgins 1977). CRP grassland plantings in this region will be represented by a wide array of seed mixtures ranging from warm-season native perennial grasses to cool-season introduced perennial grasses and legumes. The quantity and quality of CRP grasslands being established will be an enhancement to many species of resident and migratory wildlife.

Wildlife Production

Several studies have shown that these type grasslands are important to white-tailed deer and a large number of species of upland nesting birds ranging from ducks, gamebirds and shorebirds, to hawks, owls, and passerines (Duebbert and Lokemoen 1976 and 1977, Higgins et al. 1984, Kirsch et al. 1973, Klett et al. 1984). Duebbert and Kantrud (1974) have compared avian production between seeded perennial grasslands and annually-tilled croplands and showed that seeded perennial grasslands produced many more young birds than croplands. Furthermore, wildlife production from planted CRP grasslands can be enhanced even more with some type of predator removal or control (Duebbert and Kantrud 1974, Sargeant and Arnold 1984).

Bridging Isolated Wetlands

On the approximate 1.2 million wetland basins protected by FWS perpetual easements, unlike WPA's and National Wildlife Refuge lands, there is little or no provision for adjacent upland cover for nesting birds. Upland nesting ducks and shorebirds require a combination of wetland and upland grassland to be effective producers. CRP grasslands will help provide this missing habitat component close to thousands of acres of easement wetlands; hence, waterfowl production will be enhanced.

The FWS has recognized the overall importance of CRP grasslands to easement wetlands within the prairie pothole region, and have offered landowners with FWS easements on or immediately adjacent to their acreage a bonus payment of $5 per acre annually for the right to perform additional wildlife management operations on the CRP land. Examples of such operations include wetland restoration, placement of man-made nesting structures or predator removal.

Another positive benefit of having CRP grassland adjacent to wetlands is that the grassland will help impede soil erosion and pesticide movement into wetlands, which should improve water quality for groundwater recharge as well as wildlife.

Public Lands Benefits From the CRP

There is considerable concern in the Northern Plains about over-harvest of some species on small areas of public lands receiving too much public use (Jessen 1970). In other areas, increased recreational use of public lands is a by-product of restrictions on access to nearby private lands. The addition of CRP grasslands into much of this region will provide additional suitable undisturbed uplands for sportsmen if farmers allow public access on these lands.

Sportsman/Agency Benefits from the CRP

Obviously, the increase in grassland habitat from the CRP will result in a greater supply of wildlife for both consumptive and non-consumptive user groups. Any increase in user participation equates to socio-economic gains for both public and private enterprises including landowners. Unfortunately, fish and game agencies lack methods of accurately predicting the increases in wildlife production from land retirement programs like the CRP. In the Northern Plains, wildlife enhancement by the CRP will certainly exceed that of the USDA's Water Bank Program of the 1970's and 1980's, but probably not exceed that of the USDA's Soil Bank Program of the 1950's or the Cropland Adjustment Program of the 1960's.

The lesser prospects for wildlife populations enhancement during the CRP contract years stems, in part, from the present lack of abundant breeding populations, particularly of ring-necked pheasants and several species of prairie ducks whose regional and national populations are the lowest they have been in many years (USDI-CWS 1986).

PROBLEMS EXPECTED DURING THE CRP CONTRACT PERIOD

Age-Related Quality of CRP Grassland

In a five-state study in the Northern Plains, Higgins and Barker (1982) found that grasslands established with similar seed mixtures as being used in the CRP grasslands generally did not

maintain maximum structural qualities for more than 7 years. Their results showed that planted grasslands reached their maximum height and density during the 3rd to 5th growing seasons and thereafter reduced in these structural qualities. However, any overall quality reduction effects in CRP grassland plantings will likely be moderated by the sequential establishment of stands over a several year sign-up period.

Structural qualities of planted grasslands can be maintained for longer periods of time, and low quality, "sod bound" stands can be temporarily rejuvenated by periodic treatments with prescribed fire, mowing and haying, grazing, fertilization, or with aerating by shallow tillage (Higgins 1987, Duebbert et al. 1981). However, evidence (Higgins and Barker 1982) suggests that most CRP stands in the Northern Great Plains will not need any rejuvenation treatments during the 10-year contract period, and those that may, should only need one treatment during the 10-years and usually not until after the 6th growing season. Thus, we recommend against any sequence of annual treatments, but that any rejuvenation treatment be done in as short a time as possible. Much more research is needed on maintenance and rejuvenation methodologies relative to planted grasslands and the response of wildlife to these management practices.

Weed Problems

Noxious and problem weeds are expected to occur in CRP grasslands in the Northern Plains because of the perennial presence of seed banks. Higgins and Barker (1982) found that noxious and problem weeds occurred infrequently among grassland stands, but when they did occur the area affected was usually large on a per field basis. Negative aspects of noxious and problem weed control include reduction in nesting cover by mechanical control methods. Control of weeds with herbicides can reduce the compositional quality of grassland stands by decreasing the abundance of legumes and other naturally occurring forbs within or adjacent to grasslands receiving herbicide applications. The effects of herbicides on wetland flora, fauna and water quality are largely unknown.

POTENTIAL USES OF CRP GRASSLANDS IN POST-CONTRACT YEARS

The future uses, economic or otherwise, of CRP lands during post-contract years will be largely dependent on the conservation plan designed for each farm prior to January 1, 1995 and the net economic gains the landowner can expect to get from each parcel of land.

As outlined earlier, lands with some type of perennial grass and legume cover can sustain more wildlife than lands under conventional annual-tillage cropping systems. Thus, for the purposes of wildlife management, we recommend the continuance of perennial grass cover on CRP lands even in post-contract years.

There are many potential post-contract uses of CRP lands in the Northern Plains region, but they can be grouped into three general categories; supplemental, alternate management, and reinvestment. Supplemental uses are those that can be done in conjunction with other land management activities at little or no extra cost or effort to the landowner. Examples of supplemental uses of CRP grasslands include honey production and charging access fees for hunting and other recreational activities.

Alternate management uses of CRP grasslands will usually, but not always, require some extra cost and effort in order to provide a sustaining income return to the landowner. Examples of alternate management uses of CRP grasslands includes the production of hay or pasturage for livestock, grass seed, bird feed, and the establishment of shooting preserves or dude ranches that provide rural experiences for urban citizens. The latter two uses require major changes in both land and people management including significant investments in advertising and higher risk insurance.

Reinvestment uses of CRP grasslands generally requires no extra cost or effort by the landowner, but they may eliminate the acreage for red meat or grain production except in times of disaster or national emergency. Examples of reinvestment uses of CRP grasslands include a sequential lease of the same land into another land retirement program by the owner, the fee title purchase of the area by another person or group, or a long-term or perpetual easement of the land use rights by a person, a public conservation agency, or a private conservation organization.

SUMMARY AND RECOMMENDATIONS FOR THE CRP

The CRP program is expected to be very compatible with ongoing wildlife management activities in the Northern Plains, and particularly so in regard to the FWS's wetlands easement program. Few maintenance or management problems are expected with CRP grasslands after their establishment; however, there are some concerns about the future of CRP lands during post-contract years. The following recommendations are provided to address these concerns.

1. Standards for establishing and maintaining quality herbaceous cover during the CRP contract period should be followed. To avoid harm to nesting wildlife, weed control and other maintenance activities, if necessary, should be done mostly before April 20 or after August 1 in the Northern Plains region, and not on an annual basis.

2. There is a need for USDA to continue to work with landowners and tenants before their contracts expire to ensure the basic merits of the CRP are sustained beyond the contract period for the long-term good of soil and water quality protection and wildlife production.

3. Agencies should put mandatory standards in place for the type of cover that should be planted on contract areas and stick with them. In several instances, the initial lists of plant species recommended by a states' CRP steering committee were later compromised because of landowner complaints. In essence, the compromises often allow species that have little value for wildlife or forage to be planted because it is cheapest to buy and establish. Convincing farmers and ranchers that investing in quality seed of species that are site adapted and provide useful wildlife habitat should be a paramount educational goal.

4. We recommend that increased emphasis be given by USDA and other agencies to take the opportunity to restore currently drained wetlands in conjunction with the CRP. Restored wetlands can provide society with a multiple of recreation, economic, and functional values. Foremost among them is the capacity for wetland basins to retain potential downstream flood water.

5. Priority should be given to those uses of CRP grasslands that are most compatible with the original purposes for which the Program was established. In order to provide the long-term (> 10 years) benefits to society as a whole, there is also a need to continue to prevent CRP lands from eroding in the post-contract years, and to keep them providing long-term public benefits without excessive public costs.

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History and Economics of Farm Bill Legislation and the Impacts on Wildlife Management and Policies

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Abstract.--Land retirement has taken two forms, long-term (Soil Bank) and annual (set-aside). Long-term contracts require permanent vegetative cover, thus increasing pheasant populations and attracting nonresident hunters who stimulate state and local economies. Annual contracts with no vegetative cover are detrimental to pheasant populations and do not attract hunters or their monetary expenditures.

The Conservation Reserve Program (CRP), along with swampbuster, sodbuster, conservation compliance, conservation easements, debt restructuring and multi-year set-aside, in the Food Security Act (FSA) of 1985, represents the most radical departure in federal farm legislation in many decades. Even those who have devoted an entire career to bringing some degree of logic to commodity/conservation features of farm programs are surprised by this Act.

It is premature to celebrate accomplishments of the conservation provisions of the 1985 FSA, even though they have great potential for achieving public benefit. In fact, there is room for some apprehension. In my view, and others share a similar opinion, the U.S. Department of Agriculture (USDA) has a demonstrated record for failing to adequately capture fish, wildlife, soil conservation and water quality benefits under past farm programs. Attempts even now are underway to emasculate sodbuster, swampbuster and conservation compliance. Annual set-aside programs, in spite of multi-year contract authority, continue to degrade wildlife habitat and water quality and accelerate soil erosion.

At least for the present, implementation of CRP has been handled reasonably well with regards to wildlife benefits. However, some exceptions can be noted. The Missouri Department of Conservation has been trying to reverse state and local Agricultural Stabilization and Conservation Service (ASCS) rules that require CRP acres to be mowed annually as a weed control measure. The Wyoming Game and Fish Department's request to not allow monospecific plantings of crested wheatgrass has fallen on deaf ears.

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The ironic part about CRP is that it took so long to implement a land retirement program having some common sense. Certainly, long-term programs are not new. Under the 1936 Farm Act, a vegetative cover crop was required on land out of production. That program idled 43 million acres in 1941. The acreage idled between 1943 and 1953 never exceeded 6.4 million acres, and was devoted to production of legume seed.

The effect of long-term land retirement under the 1936 Act on established pheasant populations in the Midwest and Northern Plains was dramatic. Between 1936 and 1942, more than 12% of the Nation's cropland lay idle under a cover of protective vegetation. This expanse of safe nesting cover pushed already expanding pheasant populations even higher. The pheasant harvest exceeded 83 million birds in Iowa, Minnesota, Nebraska and North and South Dakota between 1940 and 1950 (Kimball et al. 1956).

Those same pheasant populations declined sharply as retired land went under the plow to meet wartime needs. This expansion of cropping also coincided with a technological revolution underway in agriculture. As advances in farm technology and intensive use of cropland continued following the war years, surplus commodities again plagued agriculture. Land retirement programs were again instituted. This time in the form of the Soil Bank's Acreage Reserve and Conservation Reserve.

The Soil Bank Acreage Reserve was used in 1956, 1957 and 1958, and required no cover. It peaked in 1957 with 21.4 million acres. In 1959, with no land in the Acreage Reserve, 22.5 million acres were in the Conservation Reserve. Soil Bank Conservation Reserve contracts were for 3 to 10 years and planted to a cover crop. The Conservation Reserve peaked at 28.5 million acres in 1961.

Throughout their range, pheasant populations began an almost immediate recovery. Pheasant responses to the Soil Bank's Conservation Reserve was typified in South Dakota (Dahlgren 1967). That state's pheasant population in the mid-50s ranged from 4 to 6 million birds, pre-hunting season. With 1.8 million acres in the Soil Bank under vegetative cover, pheasant numbers increased to 8 to 11 million birds.

The Soil Bank's long-term contracts had another positive effect on South Dakota. Aside from any conservation benefits, local and state economies were enhanced. The near doubling of pheasant numbers in South Dakota produced a dramatic increase in nonresident hunters -- from 20,000 pre-Soil Bank to 70,000 at its peak, a 250% increase (Erickson and Wiebe 1973). Each of these additional nonresident hunters spent an estimated $200 while in the state (Matson 1964). If, as economists claim, each new dollar circulates through the economy six times, nonresident hunters attracted by more pheasants as a result of Soil Bank cover annually generated $60 million in economic activity. This stimulus to the economy was an unexpected spin-off of a USDA program designed to curb agricultural surpluses.

Even as the Soil Bank operated at more than 28 million acres, surpluses continued to accumulate. But attitudes relative to land retirement methods were undergoing change in Congress. Many elected officials had received criticism for allegedly moving farmers off the land, and thus undermining local economies. The reasoning was that farmers who put their entire farms in the Soil Bank and moved to town no longer purchased agricultural equipment and supplies from local businesses.

Whether the allegations were true or not, Congress responded by enacting legislation that authorized the feed grain program in 1961 and the wheat program in 1962. Through these two programs, land was idled on an annual basis. With both programs operating in 1962, nearly 39 million acres were retired in addition to the approximately 26 million acres still in the Soil Bank. For practical purposes, the Soil Bank ended in 1970 with 53 million wheat and feed grain acres out of production.

Given the total amount of land out of crop production, one would have optimistically expected pheasants to have reached all-time highs. This was not the case. Despite USDA regulations and claims to the contrary, cover requirements, euphemistically termed conserving uses, were lax and seldom enforced. In fact, with 53 million acres of idled cropland in 1970, pheasant populations had fallen below their pre-Soil Bank level.

The situation again is clearly illustrated in South Dakota. In 1960 and after, no new Soil Bank contracts were available, and acreages began to decline from the high of 1.8 million acres. Pheasant numbers likewise began to fall rapidly, as did the number of nonresident hunters. By 1971 the Soil Bank, with its permanent cover, was history. South Dakota pheasant numbers were below 4 million birds--a 70% decline--and 50,000 nonresident hunters who had pumped millions into the economy failed to show up.

South Dakota still had more than 3.0 million acres of land out of crop production. However, annually retired land with no cover produces few pheasants. Field checks of 8,106 ac. under annual contracts in South Dakota showed that 65.4% had no cover and 4.1% were mowed (Dvorak 1971).

Concern for dramatic declines in pheasant numbers, even with massive land retirement programs in place, prompted a joint effort by 13 state fish and wildlife agencies to document on-the-ground conditions of annual set-aside acreage. Idled cropland on more than 3,500 farms was surveyed. Of the 121,000 ac. checked, 57% had no cover. Of the remaining 43%, half had a grass/legume cover seeded the previous year and half a newly planted cover crop, mostly late-seeded oats. Mowing, plowing and discing of set-aside cover began in June, and, by December, over 85% of the new or established seedings were eliminated (Berner 1984). Subsequent surveys produced similar results; i.e., land with marginal value to ground nesting birds.

The state fish and wildlife agencies, through a newly formed Farm Program Committee, brought the set-aside survey results to the attention of USDA on several occasions. Nonetheless, no changes to regulations on conserving uses of set-aside lands were made. The fact that annual programs allowed summer fallow and late seeding of cover and stimulated early destruction of cover was never corrected.

Frustrated by a perceived lack of action, the Farm Program Committee, now involving 29 states, took its case to Congress. They sought changes in land retirement practices through the 1973 Farm Bill, then under debate. That effort culminated in a provision authorizing the Secretary of Agriculture to enter into "multi-year" set-aside contracts (four years under the Act), cost share for establishing cover on multi-year set-aside lands, and purchase easements in floodplains, shorelines and aquatic areas.

In retrospect, implementations of the conservation features in the 1973 Farm Act were ineffective. A concurrent disappearance of crop surpluses led Secretary Butz to call upon farmers to plant from "fence row to fence row", Rasmussen (1982). Hence, little importance or funding by Congress was given to conservation provisions. This philosophy neatly meshed with a sudden expansion of commodity exports due to a weak U.S. dollar, an oil embargo and crop failures in a number of foreign countries. Land retirement--long or short term--became a non-option in Congress and the Administration.

The benefits of promoting extensive crop production, primarily for export, were ephemeral. A global recession, other nations becoming exporters of major agricultural commodities, and a stronger dollar caused exports to decline between 1981 and 1983. The result was a deepening financial crisis on U.S. farms. By 1983, American farmers were over $200 billion in debt (Sampson 1984). Congress' solution was the most costly commodity support program in history. The infamous Payment-in-Kind (PIK) program took 80 million acres out of production at a cost of $12 billion.

PIK was, at the same time, proclaimed as a great conservation achievement. There was a claimed 1.6 tons per acre or 20% reduction in soil erosion. From a different perspective, if soil loss on cropland with protective cover can approach zero, PIK achieved only 20% of its potential.

USDA likewise touted PIK for its wildlife benefits. State fish and wildlife agencies, however, had conducted their own field checks and reached different results. Their data showed that, of the 43 million PIK acres in the Midwest and Northern Plains, over 9 million were fallowed. Another 17.5 million acres with crop residue or volunteer plants were disced by mid-July. Fourteen million acres had a late, seeded cover crop that was destroyed early. Only 2.7 million acres, or 6%, had an established grass-legume cover crop of any wildlife value. USDA claims to the contrary, PIK provided the least wildlife benefits of any annual set-aside program.

The FSA of 1985 continued the Secretary's authority to use multi-year set-aside contracts. CRP, under present authority, is limited to 45 million acres. To date, nearly 23 million acres have been accepted, and there is good reason to assume that the 45 million acre goal will be reached. However, even with CRP fully operational, sufficient acreage will probably not be taken out of production to reduce excess commodity supply.

CRP has operated under several criteria relative to eligibility. Under the 3T criteria, nearly 70 million acres of highly erodible land are eligible. About 104 million acres qualify using 2T as the standard, and eligibility increases to 118 million acres using the erodibility index of 8 or greater. With CRP fully funded and operating at 45 million acres, 73 million acres of cropland meeting one or all of these criteria are still in production.

Annual set-aside acreage for wheat and feed grains were 36.5 million acres in 1986 and 43.6 million acres in 1987, the first two years of CRP sign up. USDA anticipates annual wheat and feed grain set-aside acreage to be above 40 million acres for 1988 even with additional CRP sign ups. No information is available on the number of highly erodible acres that might be set aside under annual contracts. But, given the fact that farmers enroll their poorer land in any retirement program, it is logical to assume that a significant portion of the annual set-aside land could be classed as highly erodible. By not using multi-year contracts, USDA continues to miss opportunities for capturing public benefits at no additional cost. Wildlife habitat and water quality continue to be degraded and soil erosion is accelerated on as many or more acres than are enhanced and protected by CRP.

Some improvement in erosion control and water quality should be possible on non-CRP highly erodible lands as they come under conservation compliance after 1990. The degree to which that is accomplished remains to be seen. At this time, attempts are underway to introduce so-called "economic reality." Economic reality translates to weakening the level of control. Even the most ideal level of control does not directly equate to wildlife benefits.

It is commonplace to grow continuous row crops on adequately treated land. Where terraces, for example, are used, even they are planted to the crop. From a wildlife standpoint, such fields are of no more value after treatment than before. On the other hand, the use of multi-year set-aside contracts, in addition to conservation compliance on highly erodible lands not in CRP, offer unlimited opportunities to enhance wildlife populations, and the local and state economies they can stimulate.

How pheasants in particular, and wildlife in general, benefit from CRP remains to be seen. No measurable results are documented at this time. The U. S. Fish and Wildlife Service's National Ecology Center and state fish and wildlife agencies presently are designing survey techniques to measure vegetative composition and responses of selected species.

For the 1986 and 1987 sign ups in Nebraska, for example, a smaller than desired number of CRP bids have been offered in better pheasant range. Since historically large pheasant populations have occurred on flatter, more productive land, this should not be surprising. However, large acreages of such cropland are still being retired under annual programs. This is further justification for a sensitively managed multi-year set-aside program in conjunction with CRP. The need is there and the resources available to do just that. All that is lacking is enlightened leadership in Washington, D.C.

Achieving CRP wildlife benefits depends almost entirely on the no haying or grazing provision. It also depends on very limited use of the authority to allow these uses in declared emergencies. Given state governors' propensity to declare emergencies to open state and federal wildlife areas to haying is good reason for concern over the misuse of this provision.

Another concern for realizing CRP's wildlife potential looms on the horizon. Soon after passage, some began to assert that "non-use" of CRP land was not in the program's best interest. As a way to reduce payments, attract more landowners to submit bids and keep CRP lands in grass following contract expiration, they advocate haying and grazing.

There is no evidence that the non-use provisions of CRP are a deterrent to bringing the full 45 million acres under contract within specified time frames. In fact, although the law permits enrollment of the full 45 million acres in any one of the five years the 1986-87 "not-less-than" acreage is well ahead of schedule. Even an expanded CRP program of 65 million acres appears attainable without haying and grazing incentives.

Those who advocate haying and grazing as a means of keeping CRP lands in grass after contracts expire espouse a less than adequate solution. According to the 1977 Resource Conservation Act assessment, 20 million acres of pasture are eroding in excess of 5 tons per acre per year, and 60% of the non-federal rangeland is in fair to poor condition. There is little reason to assume that CRP lands that remain in pasture or range at the end of the contract period will be treated any better. Such treatment would be legal since, if not used to grow crop, they would not be subject to conservation compliance regulations. They could be eroding at a higher rate than if cropped with an approved conservation plan. Forgoing wildlife values for 10 years in the hope that CRP land will eventually become an overgrazed pasture is a poor trade-off.

There is no evidence that haying or grazing during the 10-year CRP contract will promote the orderly transition of 45 million acres of highly erodible and to less intensive uses. Communities where haying and grazing are now dominate land uses are by no standard riding a wave of economic affluency.

Why should an additional 45 million acres of grass solve the problem? It is more realistic to assume that additional livestock will further depress already low prices. The same is true for additional dairy cattle that would be needed to use newly created pasture and hayland, unless one considers another federal dairy herd buyout as an economic stimulus.

That CRP land can be hayed or grazed and still provide wildlife benefits has no practical basis. There may be some rationale for manipulating vegetative cover once during a 10-year contract to retain vigor; however, landowners generally do not operate livestock enterprises on a one-in-ten year schedule. Once an annual access is provided, an economic vested interest immediately develops. If then withheld, the recipient pleads economic hardship, and the demand becomes manifested in political pressure that agencies seldom can withstand. In the process, wildlife values are sacrificed. Pheasants do not vote.

Wildlife populations that will be enhanced by non-use of CRP and multi-year set-aside offer more potential for diversifying and stimulating local economies than more haying and grazing. Minnesota predicts that fall pheasant populations would increase from 1 million birds in 1986 to 5 million in 2 to 3 years with multi-year set aside. With multi-year set-aside and CRP, pheasants would increase to 9 million in 5 to 7 years.

Experience has shown that pheasant population increases of the magnitude described will attract a significantly large number of resident and nonresident hunters. It likewise shows that hunters, particularly nonresidents, expend a considerable amount of money while pursuing their sport. The potential of tens of millions of dollars added to state and local economies far exceed those that would be generated by additional livestock on, or haying of, CRP lands.

An additional benefit of retaining CRP acreages in a non-use status is less tangible, but nevertheless real. A conservation coalition representing conservation districts, wildlife, forestry, land use, range and water played a key role in formulating the conservation/commodity provisions of the 1985 Food Security Act. It should be kept in mind, however, that it was an uneasy alliance. Wildlife and environmental interests especially had traditionally opposed agricultural programs because they habitually failed to provide fish, wildlife and environmental benefits. These interests had watched as small watershed projects and Agricultural Conservation Program practices that they initially supported became little more than drainage programs. If CRP, for whatever reason, becomes a haying and grazing program as some advocate, it is unlikely that another conservation alliance will emerge in the near future.

The FSA is a notable achievement, but it is only a beginning. The combined efforts of many diverse interests are still needed to insure its implementation and continue and expand it beyond present authorization. Any attempts to initiate economic uses for CRP to the detriment of public values or weaken the other conservation provisions provided for in the law will sever that important coalition. The losers will be this nation's fish, wildlife, soil and water resources.

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The Role of Trees and Shrubs as Economic Enterprises and Wildlife Habitat Development in the Great Plains

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Abstract.--The Conservation Reserve Program (CRP) provides a means for landowners to convert highly erodible crop land into permanent vegetation that will control soil loss. Trees and shrubs are an option in practices CP3, CP4, and CP5; tree planting, wildlife habitat, and field windbreaks, respectively. Overcoming stressful growing conditions and certain CRP regulations is necessary to make planting trees and shrubs an economic enterprise. Block tree plantings for commercial purposes is limited to on selected sites, but they have intrinsic indirect values. Field windbreak plantings are highly feasible and recommended. Wildlife habitat plantings may contain a mixture of trees, shrubs, and grasses to benefit wildlife. All of these plantings can have economic and aesthetic benefits continuing decades beyond the contract period.

There are two distinctly different aspects of the role of trees and shrubs in the Great Plains; (1) as economic enterprises and (2) in wildlife habitat development. Although they will be examined separately, first addressing the economic role of tree and shrub planting, both are strongly influenced by the Conservation Reserve Program (CRP), and will be discussed within the framework of this legislation.

Two points are raised when analyzing the role of trees and shrubs as economic enterprises. The first is that planting trees and shrubs is beneficial for the purpose of protecting soil from erosion. Second, there must be some present or future economic gain for farmers to practice this conservation technique. Both of these will be discussed, but, first, it is necessary to lay some groundwork clarifying CRP guidelines and climatic restrictions of growing woody vegetation in the Great Plains.

CRP Regulations for Tree Planting

When the original CRP guidelines were distributed, several aspects relating to tree planting became apparent. Several of these are covered in other papers in these proceedings, e.g., reducing erosion, reducing surpluses of farm products, and subsidized base acres.

Close inspection of the CP3 tree planting practices reveals a clear intent to increase wood fiber production. Restrictions on CP3 and CP5 were regulated somewhat more than other practices. Opportunities for the production of Christmas trees, ornamental plants, fruit and nuts were eliminated. Some are legitimate and traditional forest products. Obviously, the lobby groups for these industries were against any future competition.

Although, nationally, tree planting for wood fiber production is a major stated goal of CRP, CP3 planting on the Great Plains is essentially limited to esthetic and recreational uses with limited opportunity for fuelwood or posts and poles. There are limited qualifying sites in the eastern portion of the Plains states where trees can be grown for wood fiber within an acceptable time frame, but most of these sites do not qualify under present soil loss tolerance restrictions.

A recent national decision by the Agricultural Stabilization and Conservation Service (ASCS) limits actual cost share payments for trees to $150.00 per acre, essentially eliminating CP3 in the more arid regions of the Great Plains. No allowance is made for the cost of special water management, such as drip

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irrigation systems necessary for proper tree establishment in these arid areas.

Plains Growing Conditions

Other papers presented in this Proceedings give details on the harsh climate and soils of the Great Plains. Such environmental conditions require special techniques for establishing and growing trees.

The eastern Great Plains vary considerably from the western plains. Precipitation averages near 40 in. in southeast Kansas, but declines to 12 in. or less near Colorado's Front Range. This is the major factor influencing growing conditions. The large variety of highly erodible land, blow sand to clay, also limits tree growth and establishment.

Role of CP3 Tree Planting

Tree planting in the Great Plains obviously involves different production goals from those of the southeastern United States. Commercial production of wood products is limited. When incorporating CP3 in the western Plains, more consideration should be given for esthetic recreation or possible fuelwood potential. Fuelwood planting in this harsh environment could yield 28 cord/acre but it might take 30-40 years to produce it.

Red cedar is another potential product showing increasing promise in the Great Plains. Markets for cedar include lumber for furniture, paneling, curio items, as well as posts and split rails. Acreages of eastern red cedar in Nebraska and Kansas have quadrupled within the last 20 years, and foresters are finding new markets for red cedar logs. Some are being exported to South Korea and Japan at this time.

Other values are associated with planting trees on the Plains. Farms and ranches with healthy windbreaks usually demand a higher sale price much the same way as a well landscaped urban residential property. Still, tree planting in the western plains often costs more to establish and maintain than can be returned over time. Supplemental irrigation is the major expense that takes the cost beyond a viable enterprise for most landowners.

For example, a $1.00 initial investment banked and compounded monthly at 8% will yield $2.21 in 10 years. Given the average Colorado tree planting installation cost of $2.50 per tree, that investment should be worth $5.50 at the end of 10 years in order to be "economical." This does not take into account the $.50 per tree estimated annual maintenance cost. To date, the best return realized is about $4.70 per tree unless trees are sold for ornamental purposes.

Role of CP5 Field Windbreaks

Field windbreaks are linear plantings of trees and shrubs designed to reduce the effects of wind on adjacent soils and crops. Wind erosion is proportional to the unsheltered distance across a field. Windbreaks interrupt that distance and reduce the erosion potential depending on the distance from the barrier in relation to the barrier height. In the western Plains, a tree barrier can be expected to attain a height of 30-50 ft. and be effective for several decades.

Tree windbreaks have a downwind effect in excess of 15 times their height. Therefore, a windbreak attaining a height of 40 feet would have an influence on soil erosion and crop protection for a distance of at least 600 feet.

But windbreaks will not solve the immediate problem being addressed by CRP on erodible lands. The purpose of this practice in the Plains should be to plant windbreaks in conjunction with grasses. A properly designed, installed, and maintained windbreak could bring the downwind field within soil loss limits and be approved for cultivation at the end of the 10-year contract period. As an added benefit, years of studies have shown increases in crop yields resulting from windbreak protection.

Livestock protection is another potential benefit from windbreaks planted in association with grass. The Montana Experiment Station found that livestock gained an additional 35 lb. during mild winters and lost 10 lb. less during severe winters when protected areas were available. Grasslands planned for grazing could have effective winter protection available at the end of the 10-year contract if they would incorporate windbreaks at the inception of a CRP project.

Before addressing the wildlife aspects of planting trees and shrubs, it is important to mention esthetics. There are numerous things that can be done to improve the quality of our living conditions with little or no regard to cost. Air-conditioning in automobiles or farm tractors cannot pay for themselves except in the comfort they provide. Additions to or remodeling of our homes often do not result in higher selling prices. These things are done in order to have a more pleasant environment in which to live. In the same manner, planting trees for woodlots, windbreaks, wildlife habitat, or just to improve the beauty of the countryside improves the quality of living that we, and more importantly, future generations will enjoy. As Aldo Leopold so aptly said, "What we do to the land is like putting a signature to it and I want my signature to be pleasing."

Economic Role of Wildlife Habitat Development in the CRP

The wildlife habitat improvement aspect of the CRP has not received nearly as much attention as it deserves and has the potential to fill a large economic void in the Great Plains region. The CP4 provision allows establishment of quality wildlife habitat including trees, grasses, and shrubs to furnish food, cover, and nesting sites. There are fewer restrictions than for most other CRP practices, and the plantings can include any permanent vegetation that is suitable for use by various wildlife populations. Several state wildlife departments are offering to help defray the landowner's share of expenses if specialized

plantings are used. For example, Colorado will cost-share up to $2,000 if a specially designed wildlife habitat is installed.

In many cases these habitats create an "oasis effect," islands of high quality cover surrounded by cultivated farm ground or seas of grass. These islands have great potential for upland game and big game population expansion. Many of the CP1 lands, although not primarily planted for wildlife, do much to improve habitat. However, they could better serve wildlife had trees and shrubs been included in the project. Small strategically placed plantings of woody vegetation could expand the wildlife capability considerably. To meet the national goal of one-eighth of all CRP lands in trees and to meet more optimal habitat design standards, many more CP1 (native grass) and CP2 (introduced grass) projects should have included trees and shrubs where possible. Not only would this have allowed for a wider variety of both game and nongame species, but it may have provided stability to the permanence of a program that could possibly end up being a huge 10-year farm land leasing project.

A recent survey made in Kansas, Nebraska, Colorado, Wyoming, and South Dakota, showed that many landowners presently plan to return their CRP lands to crops at the end of their contract period.

Many landowners are not aware of the conservation compliance part of the program or do not believe present rules will be enforced in the future. It's simple logic. A landowner is not nearly as liable to "doze" out a stand of trees as he is to plow up a stand of grass. The trees and shrubs will increase the longevity of the CRP practice by making it more permanent.

The positive aspects of planting plant materials for wildlife are often overlooked. What is the dollar value of viewing a white-tailed deer feed along the edge of a windbreak? What value can be attached to watching or filming a rooster pheasant strut through his mating ritual? What price can we place on the song of a lark sparrow that is attracted to the edge of our prairie oasis? These questions are difficult to answer, nevertheless a value is still there.

There are economic values we can place on some wildlife. The meat value of wild game harvested by hunters runs into the millions of dollars and is a direct benefit to the consumer. The landowner may benefit by charging a daily hunting fee or design a lease arrangement for hunters wishing to harvest the wildlife crop from his or her land. One economic value often overlooked is the money generated by the influx of hunters into a region because of hunting opportunities. These dollars could be substantially increased by the CRP as wildlife populations, especially upland game birds, increase.

Kansas game managers report that, in 1986, 293,000 hunters spent in excess of $55 million within the state, or $161 per hunter. A 10% increase in hunter use as a direct result of CRP increased habitat was considered very conservative. A 10% increase would generate $5.5 million per year in added revenue to the state, primarily from the purchase of goods, fuel, and lodging. A 600% roll-over effect will increase this amount to $33 million. Kansas officials envisioned that a more realistic increase might have been 20-25%.

There is a parallel analogy trend which might reflect the potential for increased hunting. In 1976, pheasant hunters numbered 145,000 in Kansas. This was during the time of soaring fuel prices which led to less field cultivation and, consequently, more available food and cover for upland game birds. The result was a mild pheasant population explosion and, by 1982, the number of pheasant hunters had increased to 196,000. This 35% increase in hunter use was caused in part by merely letting weeds grow and crop residue remain in the field a little longer. Therefore, the predicted 10% increase may indeed be conservative.

Nebraska reports 445,000 hunters spend about $90 million in their state. This amounts to approximately $200 per hunter. A conservative 10% increase would net Nebraska's economy nearly $9 million annually. With the 600% roll-over effect, $54 million would be generated.

The national average for dollars spent by an individual sportsman in pursuit of wild game is $490--considerably more than is presently spent in the Great Plains states. Hence, there is real potential to increase hunter participation and spending in this area by providing more and enhanced opportunities.

This is a small example of the economic potential due to the increase in habitat as a result of the CRP. It should be obvious that the wildlife dollar value is not one to be taken lightly.

Summary

1. There are measurable long-term economic advantages to increased wildlife habitat and tree planting. True conservation projects can rarely be tied to short-term production economics.

2. Not all benefits of forest and wildlife planting can be tied to hard dollar economics.

3. Many landowners and operators may not be aware of the conservation compliance portion of the 1985 Food Security Act, or they expect these rules to be changed or not enforced.

4. Trees and shrubs will add performance to the CRP.

5. Many conservationists are banking on the reaction of the public, to prevent conversion of CRP land back to cropland.

6. By strategically designing windbreaks within the CP1 portion of some sites, landowners should be able to meet compliance if they convert back to crops where conservation tillage alone will not qualify.

7. The regulations involved in CP3 appear to be unfair, do not enhance the initial reasons for developing the CRP, and actually prohibit much of the economic potential involved with forest production. Christmas tree and fruit and nut production should be

allowed in the Great Plains where competing industries presently do not exist.

8. The Great Plains is a unique area with needs unusual to the rest of the nation. The CRP needs more regionalized regulations in order to meet special climatic soils and even socioeconomic conditions. It is unrealistic to set standards for the south and expect them to fit the same set of circumstances of the Great Plains.

CRP Symposium -- History of the Native Plant Seed Industry, September 17, 1987

Don Hijar[1]

The history of the native plant seed industry in the United States started when livestock were introduced in 1540 by the Spanish explorer, Coronado. However, it took until 1830, nearly 300 years later, before large numbers of cattle were introduced into the Great Plains. Large cattle ranges, backed by foreign investors, took advantage of the open range.

Trappers and miners returned to the East with stories of a land of plenty. This started the great movement of the settlers to the West. To further promote settlement of the West, the government enacted the Homestead Act of 1862. This act allowed someone to claim 160 acres for a homestead with the provision that 40 of those acres had to be cultivated. In the Western Plains, the land often was not suitable for farming. A common practice was to farm 40 acres until its productivity declined, abandon that 40 acres, and break out another 40 acres of the homestead.

More grassland was plowed out during the later 1920s and early 1930s because of higher wheat prices. These higher prices were created by the demand during World War I. Because of the above average rainfall from 1927 to 1932, even more grassland was put into cropland. As a result, more cattle grazed fewer acres. This did not present a problem at the time, as the rangeland produced more forage due to the increased rainfall.

The stage was set for the worst period in agriculture's history. From 1932 to 1939, the Great Plains experienced a severe drought. Those 7 years were hotter, drier, and windier than ever recorded. Too many cattle on too few acres caused severe overgrazing. Many acres of cropland had been abandoned and had very little cover. Both cropland and rangeland suffered high soil losses due to the winds, causing the great black blizzards of the 1930s.

The economy was bad and the land was eroding tremendously. Something had to be done. Hugh Hammond Bennett, the father of Soil Conservation, pressed for an agency that could help the farmer control erosion. In 1935, the Soil Conservation Service was established.

The federal government developed a subsidy program to assist the failing farmers in getting through the depression and to cost share on recommended conservation practices. Conservation practices to treat the cropland were developed. The practice of re-seeding was developed to tie down the soil and to return this land to its most stable condition -- "native grass."

As early as 1895, there were grass planting experiments, but they were largely failures. For the next 35 years, few studies on range seedings were conducted. Not until the need arose, as a result of the Dust Bowl days, did interest resume in seeding native lands. The native plant seed industry started at that point of necessity.

The period from 1935 to 1945, was most important for the seed industry, even though few acres were seeded. During this period, we learned how to harvest, process, and plant native grass seed.

Most of the principal seed companies involved in the present Conservation Reserve Program (CRP) had their beginnings during the Soil Bank days of 1957 to 1961. The Soil Bank program, similar to today's CRP, was enacted to stabilize commodity prices by reducing the acreages in cropland and to control erosion on cropland.

There were only three principal companies involved in warm season native grasses during the Soil Bank era: Rudy-Patrick, Kansas City, Missouri; Johnston Seed Co., Enid, Oklahoma; and Miller Seed Co., Nebraska. Other seed companies that began during that period were Garrison Seed Co., Hereford, Texas; Bamert Seed Co., Muleshoe, Texas; George Warner Seed Co., Hereford, Texas; Arkansas Valley Seed Co., Rocky Ford, Colorado; and Sharp Brothers Seed Co., Healy, Kansas.

During the Soil Bank era, most of the plant materials used were from wild harvest. Few varieties had been developed or released, and even fewer were under production for commercial use. Combines were used for harvesting, but the crop had to be somewhat damp to prevent shattering. The seed was harvested and put into large burlap bags out in the fields which were turned regularly to dry. Oftentimes, the core would spoil if the bags were not turned frequently or if the seed was packed too tightly.

Today, the combine is also used, but many companies are swathing the grass into windrows and allowing it to cure out in the field. The window is then picked up and run through the combine. This method requires less handling to dry the material.

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The areas seeded during the Soil Bank are essentially the same ones being seeded under the CRP today. The principal grasses used during the Soil Bank in the Great Plains were blue grama *(Bouteloua gracilis)*, sideoats grama *(B. curtipendula)*, and little bluestem *(Schizachyrium scoparius)*. Grasses of secondary importance were switchgrass *(Panicum virgatum)*, sand dropseed *(Sporobolus cryptandrus)*, and sand lovegrass *(Agropyron smithii)*. Today, under the CRP, the principal grasses are basically the same with the addition of western wheatgrass. We are using as many as 15 other native grasses now in the CRP that could be categorized as of secondary importance.

Probably some of the largest harvests of native grasses occurred during the Soil Bank era. One company reported a harvest in 1957 of approximately 700,000 lb. of western wheatgrass in northeastern Colorado. Few of those acres remain in grass today. The western wheatgrass yielded 300 lb. of seed per acre. This is similar to western wheat yields under irrigated production. It required 6 combines 3 to 4 weeks to harvest this seed. Since then, there has not been a harvest of western wheatgrass of this magnitude in northeastern Colorado. In 1987, approximately 200,000 lb. of native western wheat, or 1/3 of the western wheat harvested in 1957, was harvested in southeastern Colorado. This is considered an exceptional harvest of western wheat by today's standard for Colorado.

In 1956, one company harvested 1.5 million pounds of native blue grama -- the average pure live seed (PLS) percentage was 42%. In 1959, approximately 30,000 to 40,000 acres of blue grama were harvested on the Marfa Highlands of southwestern Texas. The average PLS was only 25%. Other harvests between 1956 and 1981 were small compared to the 1956 harvest. In 1981, the harvest was phenomenal and it compared to the 1956 harvest of 1.5 million lb. The average PLS was 46%, slightly better than the 1956 crop. The blue grama harvest of 1986 was small compared to the 1956 and 1981 harvests; the average PLS was less than 20%. In fact, much of the material contained less than 10% PLS.

In 1957, one million pounds of little bluestem was harvested near Abilene, Kansas by one seed company. It took 2 months to harvest, with 150 people sacking the seed and loading 89 semi-trailers. That seed was all sold in one year. The little bluestem harvest of 1986, by comparison, produced approximately 2.5 million lb. and will be used for the next two to three years.

In the native plant seed industry, one must take advantage of seed crops when they are produced, because it may be 10 years or longer before another crop worth harvesting occurs. For example, in 1957, 250,000 lb. of native sideoats grama was harvested near Adams, Oklahoma, but the very next year that same area was covered with western wheatgrass.

Although some varieties of grass seed were released in the 1950s and 1960s, the technique to grow grass seed had not been fully developed. To grow grass seed varieties under dryland conditions was not economically feasible. Yields could not be predicted or controlled. A more dependable technique for producing seed was needed. The technique for growing varieties of grass under controlled production was developed between 1952 and 1961. This technique consists of irrigation, row planting, cultivation, fertilization, and weed and insect control.

The technique of growing warm season species under controlled production was mostly complete by the end of the Soil Bank era in 1961. Because of this, nearly all the seed used for the Soil Bank program was wild harvest. Growing seed agronomically can ensure that a harvest will occur every year for most species, except for very unusual weather conditions.

During the period between the Soil Bank and CRP, economics dictated that farming was more profitable than ranching. Rangeland was converted to cropland and the need to establish permanent pasture was drastically reduced. From 1961 to 1986, many of the companies that were involved in the native plant seed industry during the Soil Bank had to turn to other products to stay in business. Many of the Texas and New Mexico companies, for example, began producing hybrid grain sorghums. For the last 25 years, there have been few seed companies that could make a living solely on native warm season grass seed. The native plant seed industry could not rely on agriculture as a marketing outlet for native grass seed.

During these years the Nation adopted a new philosophy -- protect the environment. Consequently, the Environmental Protection Agency was created and such laws as the Mine Land Reclamation Act of 1973 was put into effect. Because of these types of environmental agencies and laws, a new demand for native plants developed.

This new demand was not just for native warm season grasses, as was the case during the great drought of the 1930s or during the Soil Bank program. The demand was for much greater species diversity -- not just reclaim the land, but reclaim it to its original plant community composition.

Although species diversity has been demanded by the environmentalist for reclamation projects, the Soil Conservation Service (SCS) is using the same basic species today for the CRP as was used during the Soil Bank. The old saying that, "The more things change the more they stay the same," must be true. Twenty-five years have passed since the Soil Bank program ended, and we are again using the same combines to harvest the same grasses. We are still planting with the same drills. The SCS is still using the same methods. And the farmer is wishing that he was still paying the same prices for grass seed. Maybe some things do change.

Implications of Changes in the Regional Ecology of the Great Plains

Linda A. Joyce and Melvin D. Skold[1]

Abstract.--Environmental, ecological, and economical factors are shown to affect land use in the Great Plains. The most recent government-sponsored conservation program will induce another series of changes in the landscape of the Great Plains. However, other potential changes in the Great Plains may overshadow the impact of the Conservation Reserve Program.

Changes in land use have been driven by economics, demographics, and government policy. The most recent government-sponsored conservation program, the Conservation Reserve Program (CRP) established under the Food and Security Act of 1985 (FSA), could affect 20% of the Nation's cropland. Within the 10 Great Plains states, 29% of the total cropland area is eligible for CRP. As of the fifth signup in mid 1987, 12.9 million acres within the Great Plains have been accepted into the program (USDA ASCS 1987). There are many questions concerning the consequences of the CRP in the Great Plains and the Nation. Will the CRP meet the national goal of reducing soil erosion on cropland? In meeting this goal, what shifts in land use will occur within the Great Plains and how will this affect the regional ecology, and economy?

This paper evaluates the potential consequences of the CRP in the Great Plains by examining; (1) the landscape within which cropland acres are set, (2) the forces of land use change within the region, and (3) the interaction of CRP with other potential land use changes. Subregions in the Great Plains be defined herein as the Northern Plains of North and South Dakota, Nebraska, and Kansas; the Southern Plains of Oklahoma and Texas; and the Mountain states of Montana, Wyoming, Colorado, and New Mexico. These subregions are defined by data collection procedures and differ slightly from subregions defined elsewhere in this proceedings.

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The Great Plains Landscape

Environmental Variability

The variability of climate within the Great Plains affects the amount and type of vegetation on rangeland and pasture (Herbel and Baltensperger 1985, Moore and Lorenz 1985). Climatic events such as unpredictable rainfall, severe drought, and damaging hail influence agricultural land uses. Circumvention has been attempted with irrigation, alternative crops such as winter wheat, or grazing systems dependent upon spring through fall grazing only.

The influence that climatic variability has on land use can be examined using an index of forage production variability (Sala et al. 1988). This index is production in favorable years minus production in unfavorable years divided by the average (fig. 1). Thus, a value of 0.9 indicates that the range in production is almost as great as the mean, a highly variable system. As the value approaches zero, forage production becomes more predictable. Based on this index, forage production in the Northern Plains appears less variable than in the Southern Plains.

The spatial pattern of CRP signups reflects this pattern in climatic variability. CRP acres are densely clustered in the area of the greatest variability (corner of Colorado, Kansas, Texas and Oklahoma) and towards the southern part of the Great Plains (Reichenberger 1987). Enrollment in the Soil Bank program also showed a similar clustering of acres in the area of greatest variability (Reichenberger 1987). Thus, environmental vari-

ability coupled with government programs affects the landscape pattern of crop and pasture land use.

The Historical Landscape

Prior to European settlement, North American ecosystems were relatively unaltered by human impact, particularly when compared to the European landscape. The Great Plains climax vegetation types, as described by Stubbendieck in these proceedings, evolved within a complex set of relationships between plants, animals, and fire. While a complete description of these pre-settlement ecosystems would be valuable in determining the ecological balance without extensive or intensive human labor and capital input, only limited estimates of wildlife populations, primarily big game, exist. Large numbers of herbivores such as antelope and bison roamed the plains prior to 1830, when settlers first arrived. These big game numbers are highly speculative, but are of interest for comparison with contemporary numbers of the same species and with historical and contemporary numbers of domestic grazing animals.

Historical bison estimates range from 30 to 60 million (Wagner 1978). Seton (1929) placed historical numbers at 60 to 75 million for the entire western range of the buffalo. For this study, a conservative estimate of 30 million for the Great Plains portion of the buffalo range will be made. Buffalo numbers declined with the massive buffalo slaughter associated with the fur trade. By the 1900's, these herds had been seriously depleted. Seton (1929) reported an estimate of 14 million buffalo nationwide. We have used a value of 7.5 million for the Plains census in 1900.

The original range of antelope included most of Texas, Oklahoma, Kansas, all of Nebraska, North and South Dakota,

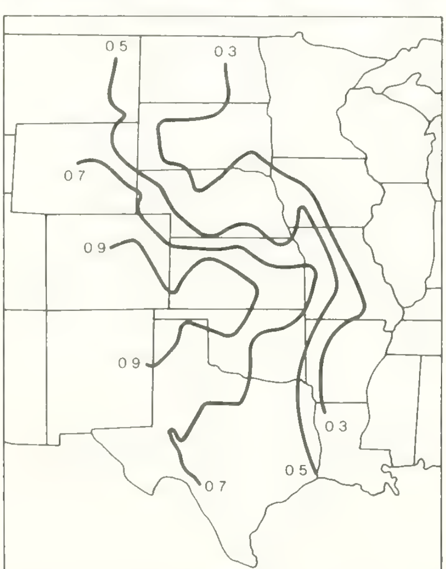

Figure 1.--Regional variability in forage production between favorable and unfavorable years in the Great Plains (after Sala et al. 1988). Variability estimated as (production favorable-production unfavorable)/average production.

and all states further west (Seton 1929). Seton estimated antelope density at 30 per square mile in the better half of their range (the Plains east of the Rockies and California). If their Great Plains range was approximately 1 million square miles, a density of 30 per square mile would result in a historical estimate of 30 million antelope. Numbers had dropped to an all time low in the early 1920's; e.g., Nelson's (1925) Bulletin reported 16,449 antelope for Great Plains states in 1922-1924. Since that time, antelope have been increasing.

Seton (1929) described the original range of mule deer covering the western edge of Texas and Oklahoma, half of Kansas, nearly all of Nebraska, all of North and South Dakota, and all states further west. He estimates that mule deer roamed this range at a density of 5 deer/square mile. Estimating approximately 800,000 square miles as the range, the deer population would be 4 million. Seton (1929) reported that white-tailed deer were absent from open plains and for this paper, their historical numbers were considered insignificant. However, recently, white-tailed deer have expanded westward along the riparian areas of the Great Plains, and have increased substantially in number.

Recent historical numbers for bison, mule deer, white-tailed deer, and antelope were obtained from U.S. Fish and Wildlife Service Big Game Survey, National Rifle Association Hunting annual survey, USDA Forest Service (1980), state fish and game annual reports, Council for Agricultural and Science Technology (CAST) (1986), U.S. Department of Agriculture 1939, and other data sources.[2]

To give a picture of the historical grazing pressure and for comparability across animal types, wildlife population numbers were converted to animal unit months (AUMs) using a method described by Wagner (1978). Wildlife numbers were reduced by the fraction of young likely to be found in them--40%. The remainder were treated as adults and used to estimate wildlife AUMs. AUM conversions were taken from Heady (1980): 1 Elk = 1 AUM; 5 Deer = 1 AUM; 5 Antelope = 1 AUM; Bison = 1 AUM. Because the grazing pressure of domestic livestock varies over the year, and wildlife remain on the land for the entire year, an annual estimate of grazing pressure was computed. All AUMs for native fauna were multiplied by 12. Nearly 300 million AUMS were supported on the Great Plains prior to the introduction of domestic livestock (fig. 2). Grazing pressure of native fauna has decreased, largely because animal numbers declined under severe hunting pressure in the 19th century (Schmidt and Gilbert 1978).

The initial movement of settlers west of the Mississippi coincided with the movement of livestock operators northward from Texas. The need for Confederate supplies briefly stimulated the western cattle industry, until the Union blockade. After the war, however, few cattle were found in the East, and economic incentives were great for the West to supply these eastern markets (Stoddart et al. 1975). By 1880, there were 10

[2]*C. Flather, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO, Personal Communication.*

million cattle and 10 million sheep in the Great Plains (fig. 3). These numbers grew over time, even with the continual conversion of rangeland to cropland. Horses and mules peaked around 1920 and declined thereafter with the advent of the tractor. Sheep numbers peaked and remained high between 1930 and 1945, but have declined since with decreasing per capita consumption of lamb and mutton and the advent of synthetic fabrics. Cattle numbers have risen consistently since the start of the beef industry.

Livestock numbers have been converted to AUMs, using the method described by Wagner (1978). AUM conversions were taken from Heady (1980): 5 Sheep = 1 AUM; 5 Goats = 1 AUM; 1 Horse = 1 AUM. Wagner (1978) assumed that, prior to 1940, cattle were finished on the range, not in feedlots. On the Great Plains, cattle would also have been finished on the range. Seasonal forage availability in the Great Plains may have been longer than in the intermountain region, thus we have taken 75% of the total numbers and multiplied by 12 to obtain an annual

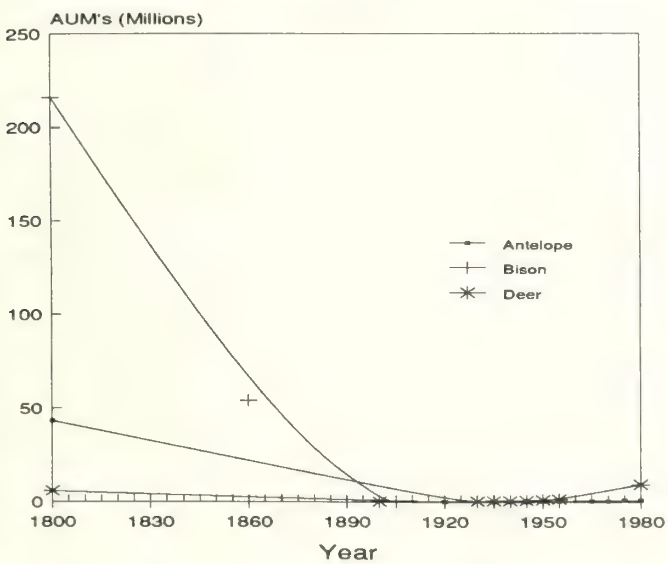

Figure 2.--Conjectured big game grazing pressure on the Great Plains region from 1900 to 1980. Wildlife population numbers from historical and recent inventories were converted to AUMs.

value for livestock AUMs. After 1940, Wagner (1978) assumed that irrigated pasture, cropland products, and feedlots were important. While pasture was important in the Great Plains, the amount of land in range, often good rangeland, is larger relative to the amount that could be found in the Intermountain West. Thus, we have calculated the highly speculative post-1940 cattle AUM's using half the numbers after 1940. Sheep and horses were assumed to be on the range 12 months.

The inverse relationship between wild and domestic grazing pressure (fig. 4) does not infer a causal relationship between decreasing wildlife and increasing livestock, but rather that the early settlers and those who followed were a new ecological force that realigned the grazing influences already present. Wild grazers were replaced by domestic grazers, and wild browsers with domestic browsers (Stoddart et al. 1975). In the 1980's,

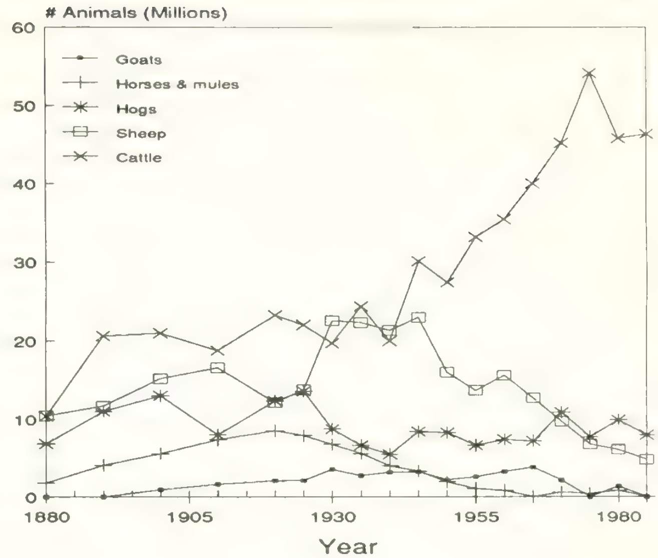

Figure 3.--Historical and recent numbers of domestic livestock on farms in the Great Plains region, 1880-1985. Data from U.S. Department of Agriculture (1982, 1986).

domestic AUM's are above the pre-settlement wildlife AUM's. These wildlife AUMS were assumed to be in equilibrium with their original habitat. The current domestic AUM's are associated with only half of the original rangeland of the Great Plains, and are sustained only at considerable inputs of labor and capital. Any desired shifts in wildlife or livestock numbers will require a recognition of the needed inputs of land, labor, or capital to produce additional AUM's from the Great Plains system.

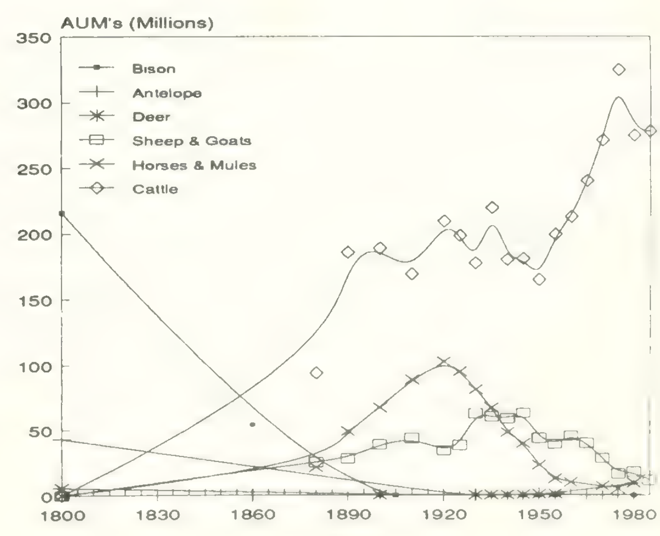

Figure 4.--Conjectured wildlife and domestic AUMs in the Great Plains region during 1800-1985. Domestic livestock numbers were converted to AUMs assuming cattle grazed rangeland only part of a year, sheep, goats, horses, mules, and wildlife grazed yearlong.

The Present Landscape

The current land use in the Great Plains is still dominated by range ecosystems (table 1). Cropland, range/pasture, and forest acreages have remained relatively static since the early 1900's (Frey and Hexem 1986). Within each of these major categories, the pattern of land use has changed. Crop plantings have shifted with economic demands and government programs. Within the past 30 years, wheat acres have seen major fluctuations; corn plantings have ranged from 10 to 20 million acres and soybean acres have increased four-fold (U.S. Department of Agriculture, 1986). Irrigation of cropland within the Great Plains has increased over the last 30 years, although this rate of increase has slowed recently.

The pattern of cropland used for crops[3] varies across the Great Plains (USDA Economic Research Service 1987). Within the Northern Plains, cropland has been used for crops with more constancy than other parts of the region (fig. 5). Within the Mountain states, the amount of cropland used for crops has been relatively constant, with a recent upward trend. Cropland used for crops remained within 12% of the base year 1977 for the Northern Plains and for the Mountain States. Within the Southern Plains, the index has ranged from 25% below to 13% above the base year 1977. This greater volatility in the Southern Plains, also seen in the forage index (fig. 1), is likely related to climatic variability and the resultant greater risks associated with farming. Government programs to reduce soil erosion and remove excess capacity from agricultural production have also been a factor.

[3]Cropland used for crops includes those acres on which crops were harvested, on which crops failed and cropland acres that were idled.

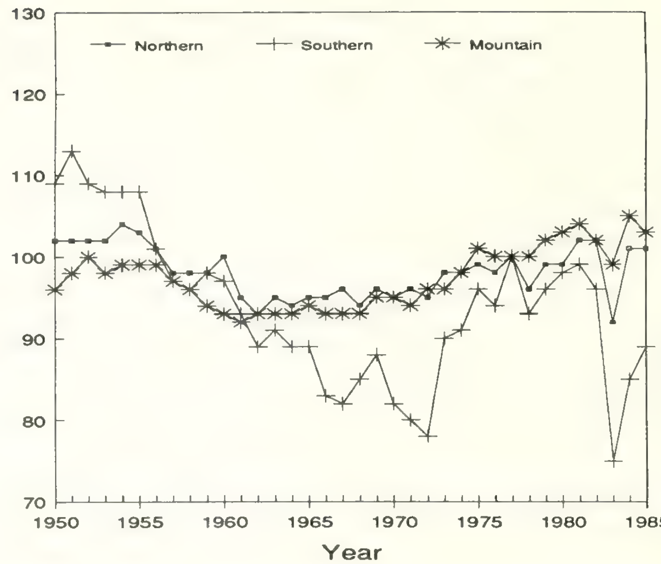

Figure 5.--Indices of cropland used for crops within the Northern Plains, Southern Plains, and Mountain states of the Great Plains. Base Year (index = 100) is 1977.

The 12.9 million acres already accepted into the CRP represent 8% of all cropland, or 1.8% of the total land base in the Great Plains (table 1). If relative regional contributions to the national CRP total remain the same, the number of CRP acres in the Great Plains potentially could increase to 20 million by the close of the program. The currently contracted CRP lands could double the number of acres in grass cover types, such as pasture, in Colorado and New Mexico, while the potential withdrawal could double these acres in Kansas and Montana (table 1). The impact of these changes will be a function of the resultant land

Table 1.--Total cropland, CRP eligible cropland, area for which cropland diversion bids are accepted, pasture, range and forestland, (1000 acres) for Great Plains States, 19871.

State	Cropland acres	CRP eligible acres	CRP acres accepted (% cropland)		Pasture acres	Range acres	Forest acres	CRP % of state
North Dakota	27,039	2,790	1,449	(7)	1,272	10,948	438	3.2
South Dakota	16,947	2,038	847	(5)	2,703	22,783	562	1.7
Nebraska	20,277	5,034	949	(5)	2,125	23,096	732	1.9
Kansas	29,118	7,032	1,980	(7)	2,241	16,909	626	3.8
Oklahoma	11,568	2,949	871	(8)	7,138	15,060	6,539	1.9
Texas	33,320	13,932	2,782	(8)	17,043	95,353	9,324	1.6
Montana	17,197	8,061	1,762	(10)	3,036	27,837	5,228	1.9
Wyoming	2,587	383	216	(8)	755	26,915	987	0.3
Colorado	10,603	5,469	1,584	(15)	1,250	24,222	4,030	2.4
New Mexico	2,413	872	455	(19)	163	40,982	4,734	0.6
Great Plains	171,069	49,100	12,895	(8)	37,726	357,894	33,200	1.8

[1]Land area data from 1982 SCS NRI (USDA SCS 1987); CRP data as of fifth signup (mid-1987) from USDA ASCS (1987).

use. For the duration of the contract period, these acres will represent idle land. After the contract period, uses such as grazing or a return to crop production can be considered.

The potential exists for the CRP to stem the changing composition of fauna on the Great Plains. Species historically associated with the Great Plains grasslands have declined in the face of trappers, market hunters, and the plow. Bison, white-tailed deer, elk, wild turkey, cougar, grey wolf, bear, and pronghorn antelope were exterminated, or radically diminished in population numbers (McConnell and Harmon 1976). While some species flourished under the new land use of agriculture, distributions of several wildlife species shifted from the intensive crop-producing regions of the Great Plains to areas where crop production was not the dominant land use.

Cropping pressures and fences in intensive livestock-producing areas have hastened the retreat of antelope into a smaller segment of its original range (Leopold et al. 1981). The sharp-tailed grouse has retreated north into Canada, leaving much of its original range in the Northern Plains (Leopold et al. 1981). Wild turkey distributions have moved south into the forested areas and west into the intermountain region, away from the large cropping areas of the Midwest (Leopold et al. 1981). Burrowing owl populations have declined largely as a result of widespread elimination of burrowing rodents, whose burrows are nesting sites for owls (Evan 1982). The long-billed curlew has been listed as one of 28 species nationwide to have unstable or decreasing population trends and the loss of short-grass prairie to agricultural development is the suspected cause of this decline (USDI Fish and Wildlife Service 1982). Intensive use of land for ranching or agricultural operations in southern Texas has been directly related to declines in the Rio Grande wild turkey (Gore 1973).

As rangeland has been converted to agricultural land, species such as quail, pheasant, rabbits, and with management, white-tailed deer, have increased. Breeding season densities of cowbirds, grackles, red-winged blackbirds, and starlings over the 1966-1976 period increased in the eastern Great Plains (Dolbeer and Stehn 1979). Baxter and Wolfe (1973) suggested that a threshold exists for agriculture and pheasant populations; below this threshold, an increase in cultivation results in an increase in pheasants; above the threshold, an increase in cultivation induces a decline in numbers. Harmon provides additional information on agricultural practices and pheasant populations in this proceedings.

The intensification of agriculture has transformed wildlife habitat in rural counties and states along the eastern edge of the Great Plains. A pattern of increased row crop plantings, decreased hay and small grain plantings, and decreases in wildlife populations has been described for prairie chickens, quail, rabbits (Vance 1976), and non-game birds (Graber and Graber 1983). This pattern of declining wildlife populations could be a prototype for other states (Karr 1981), but the increased permanent vegetative cover of CRP lands could stem this decline.

Land Use Changes

Population Growth--Urban versus Rural

Total population in the Great Plains increased from 17 million in 1950 to approximately 28 million in 1980. More importantly, this population growth occurred primarily in the urban areas, while rural population remained the same. Urban population grew from just under 10 million in 1950 to more than 20 million. This shift changes the services demanded by the population, and places different stresses on the environment.

When the population density, irrespective of urban/rural divisions, is examined, the Great Plains is much less densely populated than the national average of 64 people per square mile. This pattern is the result of the large amount of cropland and rangeland in the Great Plains. Important differences in density occur within the Great Plains. As one moves south, the population density increases. North and South Dakota have less than 10 people per square mile; Oklahoma and Texas have more than 30 people per square mile. Kansas, Nebraska and Colorado are in between these densities. Density and total population indicate where the potential for population and economic growth may be in the Great Plains.

Agricultural Industry

Intensification of production can be demonstrated for most crops over the 1950-1984 period (Skold and Young in press). The effect of technology on the dominant Great Plains crop of wheat can be examined in the annual changes in wheat production per acre. When annual per acre yield of wheat is regressed against time, a positive annual increase can be seen for each state, as well as the Great Plains region (table 2). This yield increase ranges from 0.36 to 0.65 bu/ac. per year across the states. The Great Plains increase was 0.54 bu/ac. per year. With a current wheat acreage of 46.9 million acres and a regional annual increase of 0.54 bu/ac., each year brings an additional 25.3 million bushels of wheat.[4]

Associated with this increasing trend, however, is a substantial year-to- year variability in yield. The semi-arid region experiences significant climatic fluctuations so that the coefficient of variation of annual wheat yields ranges from 20% to 38% (table 2). Consequently, when the coefficient of variation reflects a range of 7 bu/ac. around the yield mean, the 0.54 bu/ac. increase in the Great Plains annual wheat yield of 23.2 bushels per acre is easily missed. This variability makes it difficult to gauge the impact of land withdrawal programs on crop production levels.

Since the 1950s, programs have been implemented to control the supply of certain agricultural products. Acreage diversion programs have included both temporary diversions (1-year) and long-term (2- to 10-year) diversions. Long-term diversions, such as the Soil Bank of 1956 and the current CRP, require

Table 2.-- Average wheat yields, yield trends, and variability, Great Plains states (USDA Agricultural Statistics 1984).

State	1950-84 average (bu./ac.)	Coeff. of variation (1950-1984)	Ann. increase in yield (bu./ac.)	Std. error of annual increase
Colorado	22.1	31	0.49	0.08
Kansas	25.7	31	0.65	0.70
Montana	23.6	20	0.36	0.05
Nebraska	29.4	25	0.57	0.07
New Mexico	24.2	38	0.53	0.09
North Dakota	22.5	30	0.50	0.07
South Dakota	19.5	36	0.49	0.08
Oklahoma	22.8	33	0.60	0.07
Texas	20.1	34	0.55	0.06
Wyoming	23.3	24	0.38	0.07
Great Plains	23.2	30	0.54	0.05

**Based on regression analysis: y = ax + b where y = annual wheat yield; x = dummy variable for year; a = estimate of annual increase in yield. Results all significant at the 0.0001 level.*

withholding cropland from production for the term of a contract. Such idled cropland may or may not have been put to another agricultural use, as explained by Bedenbaugh in this Proceedings. The intent of cropland diversion programs is a decrease in the amount of cropland used for crops. The success of these programs can be examined in terms of the acres of cropland used for crops, or in terms of total crop production. Presumably, one acre diverted would result in one acre removed from cropland used for crops and a decline in the overall crop production of the region.

To determine what extent the increase in diverted acres correlated with a decrease in the amount of cropland used for crops, diverted acres for the 1956- 1985 period were regressed against cropland used for crops. One diverted acre, under both short- and long-term contracts, resulted in a less than one acre reduction in cropland used for crops: 0.33 acre in the Northern Plains, 0.55 acre in the Southern Plains, and 0.41 acre in the Mountain states (table 3). This less-than-one-for-one relationship between cropland diverted and cropland used for crops has been observed before; it has been termed the slippage factor (Ericksen 1976).

One of the reasons for slippage is that, as land diversion programs are implemented in the Great Plains, the proportion of crops planted on summer fallow increases. Summer fallow acres have been used to meet the program requirements for temporary diversions. The slippage from diverted acres into summer fallow provides an interesting mirror image of the cropland diversion programs. As acres are diverted, cropland used for crops (which includes cultivated summer fallow) decreases (table 3). The shift within the cropland used for crops category (from harvested

[4]Based on the regression analysis, this estimate has a standard error of 2.7 million bushels.

Table 3.--The effects of acres diverted on cropland used for crops, great plains, 1956-85 (USDA ERS 1987).

Region	Constant (1,000 ac.)	Change in cropland per acre diverted*	Standard error of change	R^2
Northern Plains	92,246	-.33	.05	.63
Southern Plains	37,762	-.55	.10	.53
Mountain States**	27,341	-.41	.10	.36

**Regression analysis: y = ax + b were y = cropland used for crops, x = diverted acres; a = estimate of the effect of diverted acres on cropland used for crop. Regressions significant at 0.0001 level.*

***Includes only the Great Plains portion of the Mountain region.*

cropland to cultivated summer fallow) is seen by the positive regression coefficients between diverted acres and summer fallow acres (table 4). Summer fallow plantings are affected by many factors other than diverted acres, as indicated by the variability captured in these regressions (table 4). The Southern Plains, where each diverted acre results in a 0.55 acre reduction in cropland used for crops, has the smallest slippage to summer fallow; each diverted acre is associated with a 0.11 acre increase in summer fallow. In the Northern Plains, a diverted acre reduces cropland used for crops by 0.33 acre while summer fallow increases by 0.27 acre. For the Mountain States, cropland used for crops falls by 0.41 acre for each diverted acre but summer fallow increases by 0.16 acre. Thus, the land diversion programs succeed in reducing total cropland used for crops, but at a less than one-for-one rate, because some of these acres return to cropland use as summer fallow.

The other measure of crop reduction programs is total crop production. Three forces operate to increase the output per acre of cropland remaining in production (not diverted); the remaining land is of overall better quality, higher proportions of the crops are planted on fallow land, and management compensates for reduced cropland. Presumably the least productive acres are diverted and some of the diverted acres end up as summer fallow.

Table 4.--The effects of acres diverted on summer fallow acres; Great Plains, 1956-85 (USDA ERS 1987).

Region	Constant (1,000 ac.)	Change in cropland per acre diverted*	Standard error of change	R^2
Northern Plains	13,153	0.27	.12	.15
Southern Plains	2,035	0.11	.03	.28
Mountain States**	9,667	0.16	.04	.41

**Regression analysis: y = ax + b where y = summer fallow acres, x = acres diverted. Regressions significant at 0.05 level for Northern Plains, and at the .01 level for Southern Plains and Mountain States.*

***Includes only the Great Plains portion of the Mountain region.*

Summer fallow yields tend to be greater than continuous cropped yields (Bond and Umberger 1979). Further, other inputs, notably fertilizer, may be substituted for land to increase production on land remaining in crops. While production should decline as cropland harvested is reduced, its decline is partially off-set by these output effects.

To determine the effect that acreage reduction programs have on the total crop production in the Great Plains, diverted acres of cropland and time were regressed against the index of crop production. The index of crop production incorporates the production of all crops in each subregion, including harvested hay. A measure of crop production more closely related to only those crops in acreage control programs would have been desirable; however, only the index of total crop production was available. Thus, for those regions where harvested hay acres are important, such as the Mountain States, the regression coefficients will be smaller than if a measure relating only acreage control crops were used. Time is included to account for the increasing yield trends observed earlier.

The small coefficients for the Southern Plains and Mountain States indicate a limited impact of diversion programs on crop production (table 5). Over the 1956-1985 period in the Southern Plains, each million acre increase in diverted acres is associated with a 1% decrease in the index of crop production (standard error of this coefficient was 0.05%). A million acre increase in diverted acres in the Mountain States is associated with a 2% percent decrease in the crop production index (standard error of this coefficient was 0.05%).

The results of these regression analyses indicate that the current CRP signup of approximately 3 million acres will be associated with only a 3% reduction in the crop production index in the Southern Plains. Approximately 3 million acres in the Mountain States will be associated with a 6% reduction. General cropland diversion programs are moderately effective in reducing the acreage harvested of crops; but, these programs have had limited effect on the reduction of crop output. Many other factors contribute to crop production in the Great Plains regions, notably climatic factors mentioned earlier in this paper.

Table 5.-- The effects of acres diverted and time on the index of crop production (1977=100) in the Great Plains, 1956-85 (USDA ERS 1987).

Region	Regression Coefficient for diverted acres[1]	Regression Coefficient for time	R^2
Northern Plains	-.0001*	2.41	.82
Southern Plains	-.001	.86	.49
Mountain States	-.002	1.58	.93

[1]Regression analysis: $y = ax + bz + c$ where y = index of crop production (1977=100), x = diverted acres, z = dummy variable for time. Regression significant at the 0.01 level.

**Not significant.*

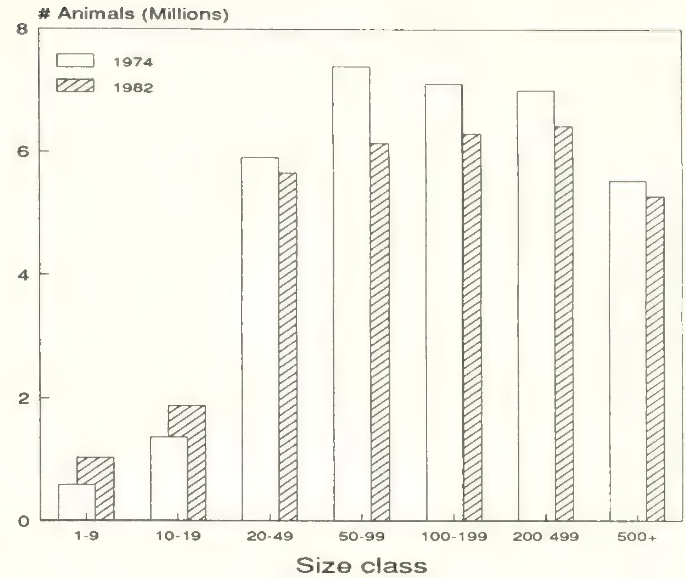

Figure 6.-- Number of beef cattle and calves by size of cow herd in the Great Plains for 1974 and 1982. Data from U.S. Department of Agriculture (1974, 1982). These numbers do not include 7.7 million steers in 1974 and 10 million steers in 1982.

Livestock Industry

Restructuring within and exits from the livestock industry affect the Great Plains economy. Recent concerns within the agricultural business community have been the agricultural credit crisis, and uncertainty about the future demand for red meat (Drabenstott and Duncan 1982, Fedkiw 1985). Pasture and rangeland, along with idle land, have been the most important sources for new cropland since 1975. During the 1975-1979 period, 64% of new cropland came from pasture, range, and idle land. During the 1979-1981 period, the number rose to 84% (Heimlich 1985).

Nationwide and within the Great Plains, the total number of farms has decreased and the size of the average farm has increased (Lagrone 1979). Average herd size of beef operations started to decline during the rapid reduction in beef cow numbers beginning in 1975 (Gilliam 1984). By 1978, the average beef cow-calf herd was 34 brood cows, and more than 58% of all herds contained fewer than 20 cows.

Changes in the number of farms and number of livestock over the 1974-1982 period reflect this overall decline. The number of livestock in herds of 20 or more animals has decreased. Within the smaller size classes, the total number of livestock has increased (fig. 6). Over the same period, no growth was seen in the number of farms with herds of greater than 20 animals (fig. 7). However, the number of farms in the small size classes increased from a little over 40,000 to nearly 80,000 farms. Similar results have been reported for Colorado where the state-wide increase in farms over the 1978-1982 period was the result solely of an increase in small farms, where small was defined as less than 179 acres (Miller et al. 1986). Farm numbers in all size classes over 179 acres declined.

The changes in beef farms by herd size class differed by state within the Great Plains. The number of small farms decreased from 1974 to 1982 in Nebraska but remained the same in the Northern Plains, and northern Mountain States. Over the same period, the number of small farms doubled in New Mexico and Oklahoma, and nearly doubled in Texas. Most of the beef was still produced on the larger farms. However, the landscape of the Southern Plains is becoming dotted with smaller size beef farms.

Government Programs and Land Use Change

National attention focused on the links between resource use, management, and soil erosion during and after the "Dust Bowl" of the 1930's. Fearing a similar circumstance in the 1950's, Congress gave recognition to the fragile environment and many acres of cropland were diverted in the Great Plains Conservation Program. An entire region was perceived in terms of its susceptibility to soil erosion. Responding to the higher commodity prices of the 1970's and encouragement by policy makers to plant, there was pressure for expansion and cropland acres increased. Here, the Great Plains region was perceived in terms of its potential to feed the world. While the concerns about the adequacy of the resource base to meet future demands resurfaced temporarily in the 1970's, recent attention has been on issues of excess capacity, resource conservation, and financially stressed farmers. These concerns affect policy that shifts labor and capital inputs within and to a region.

The regional variability in land and soil type affects the national distribution of government programs aimed at reducing crop surpluses or soil erosion. Of the 83.3 million acres of highly erosive cropland, 39.9 million acres or 48% of it lies in the 10 Great Plains States (Skold and Young in press). The three subregions within the Great Plains contain about 44% of the Nation's cropland. About 37% of the land converted to new cropland during 1975-1977 and 1979-1981 was located in the Great Plains: 14% in the Northern Plains, 11% in the Southern Plains, and 12% in the Mountain States (Heimlich 1985). Of the converted land deemed highly erodible, 17, 11, and 21% of it is in the Northern Plains, Southern Plains, and Mountain regions, respectively (Heimlich 1985). The newly converted land is more erosive than former cropland. Thus, the Great Plains has contributed a less-than-proportionate share of the new cropland but a greater-than-proportionate share of highly erosive cropland.

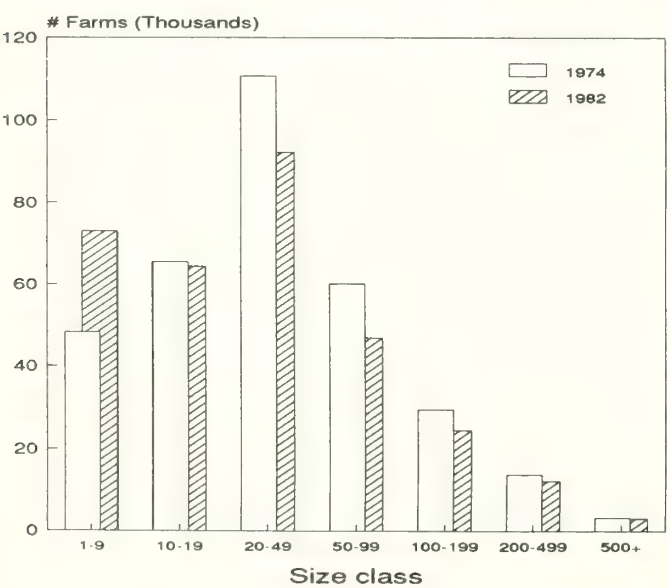

Figure 7.--Number of beef farms in the Great Plains by size of cow herd for 1974 and 1982. Data from U.S. Department of Agriculture (1974, 1982).

Table 6.-- Distribution of reductions in program crops depending on implementation strategy, Great Plains (Grano et al. 1985).

Strategy	Percent reduction in program crops in: Northern Plains	Southern Plains	Mountain States
Retire least profitable land	18.5	35.9	6.2
Retire least profitable land with past diversion patterns	38.3	17.9	12.2
Retire targeted erodible acres	27.2	9.0	11.2
Retire only highly erosive land	7.4	1.3	1.2
Retire highly erosive land prioritized by erodibility	8.1	1.4	1.3

Different strategies in government programs for removing erosive lands from production have different consequences on program objectives. Bid pool allocation is one of the three discretionary factors in implementing the CRP that the U.S. Department of Agriculture Secretary may modify any time prior to a sign-up period. Dicks et al. (1987) concluded that using the largest possible big pool size (a national pool) provides the best achievement of a single objective goal, such as to minimize rental costs, maximize erosion reduction, or maximize crop control. State or substate bid pools tend to distribute CRP acres across the Nation, but at a loss of the single objective goal (Dicks et al. 1987).

Different strategies in government programs will also have different consequences on program participation across the United States. Bidding land out of production without regard to its erodibility reduces program crop production in the Southern Plains most heavily (Grano et al. 1985) (table 6). However, if the pattern of diversion payments realized in past programs was followed, the Northern Plains is more heavily affected. If the focus shifts from per acre profitability as the basis for including land in cropland retirement programs to the sole objective of reducing soil erosion, the Great Plains region is less affected than other regions. More erosion on a per acre basis occurs in the Corn Belt region. Even though the Great Plains has a greater than proportionate share of highly erosive cropland, the amount of erosion per acre is small when compared to soil losses per acre in other regions. The first strategy shown in table 6 is now being

implemented. Thus, the CRP may serve to stem the tide of increasing erosion levels within the Great Plains even though, at the national level, the objective of reducing soil erosion may not be optimized.

Future Land Use

Projections for the Great Plains

The impact of the CRP must be evaluated against other potential land use changes, and how those changes are implemented across the landscape. Projections of future resource production offer a quantitative way to assess whether our resources will meet future needs, given underlying assumptions. Projections are made with a set of assumptions about technology growth, export demand, agricultural management, and assume constant prices and stability in other aspects of the production environment (USDA Soil Conservation Service 1987).

Incorporating recent trends in the agricultural sector, economy and recent legislation, projections made by the Soil Conservation Service in the Second Resources Conservation Act (RCA) Appraisal suggest that significant readjustments in cropland will occur (USDA Soil Conservation Service 1987). Less than 40% of the available cropland in the Northern Plains, the Southern Plains and the Mountain States is projected to be in production by the year 2000 (fig. 8). This implies that 60% of the available cropland, a number five times greater than the potential acres in the CRP, would not be needed to supply the demands for crop production. These Great Plains acres could sit idle, move into set-aside programs, or convert to alternative land uses which would bring a higher investment, such as urbanland (USDA Soil Conservation Service 1987).

These projections are based on several assumptions concerning land use shifts. Cropland with the lowest profit per acre was identified as those acres which would be removed from crop production to reduce excess capacity and to meet the FSA Conservation Compliance provisions. Few conservation measures mitigate wind erosion, notably highest in the Great Plains. Sheet and rill erosion per acre are greater in other regions (notably, the Corn Belt), but attacking erosion by reducing acreage with the smallest profit margin per acre means that cropland in the Great Plains comes out of production. The consumer demand for less meat and a leaner meat product lowers the demand for feed-grains. Reduced export projections also place less demand for cropland.

The potential for population growth in the Second RCA Appraisal projections reflects the current population locations and greatest densities. By 2030, population in the Northern Plains was projected to be 9% less than the 1990 population. The situation was much different in the Southern Plains where the

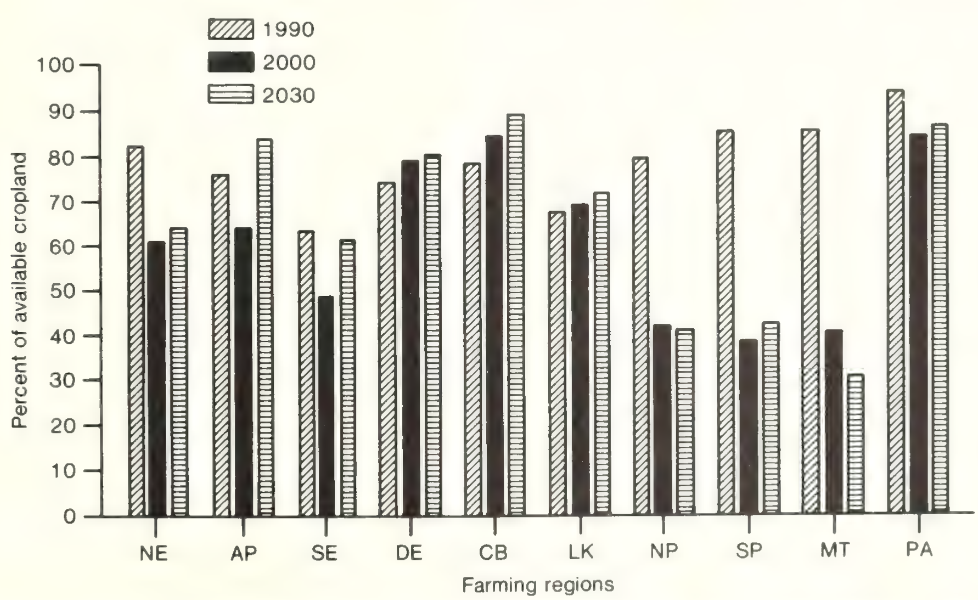

Figure 8.--U.S. Department of Agriculture projected cropland in farming regions in the United States for 1990, 2000, and 2030 (after USDA SCS 1987). Farming regions are defined as: NE (Northeast) includes the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont; AP (Appalachia) includes Kentucky, North Carolina, Tennessee, Virginia, and West Virginia; SE (Southeast) includes Alabama, Florida, Georgia, and South Carolina; DE (Delta States) includes Arkansas, Louisiana, and Mississippi; CB (Corn Belt) includes Illinois, Indiana, Iowa, Missouri, and Ohio; LK (Lake States) includes Michigan, Minnesota, and Wisconsin; NP (Northern Plains) includes Kansas, Nebraska, North Dakota, and South Dakota; SP (Southern Plains) includes Oklahoma, and Texas; MT (Mountain States) includes Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming; PA (Pacific) includes California, Oregon, and Washington.

population was projected to grow approximately 67% by 2030. The Mountain region was projected to double in population by 2030. The United States was projected to grow 22% by 2030.

These population growth estimates presume related land use conversions to non-agricultural land uses (fig. 9). By 2030, a 83% increase over the 1982 inventory of nonagricultural land was projected for the Southern Plains, a 33% increase in the Mountain States, and only a 7% increase in the Northern Plains. These urbanized acres far outweigh the currently contracted CRP acres, and could equal the potential maximum acres in the CRP program for the Great Plains.

Implications to the Pattern of Land Use

The pattern of land use in the Great Plains has changed and will continue to change. Determining the future pattern of land use on the Great Plains is a difficult task. Clearly, shifts in crop production and cropland set-aside programs will affect the pattern of land use and changes in this pattern of land use will affect other resources such as wildlife.

The impact of the RCA projected increase in non-agricultural land uses will depend on how it is distributed across the landscape. Approximately 20% of all cropland within the U.S. occurs within counties classified as Standard Metropolitan Statistical Areas (SMSA) (Gustafson and Bills 1984). Lessinger (1987) discussed the potential areas for population growth and described the area just outside of the urban commuting zone as most likely to exhibit a large growth in the future. If this area was described as those counties that are adjacent to a SMSA county and that have an urban population (residing in incorporated and

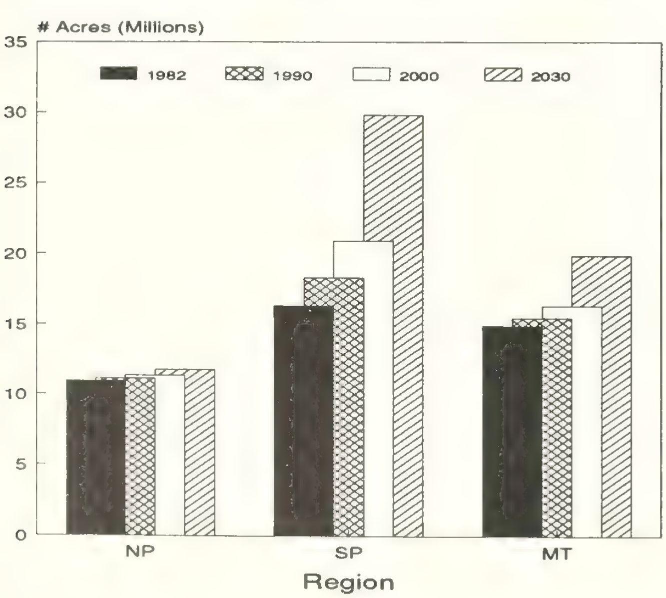

Figure 9.--U.S. Department of Agriculture projected nonagricultural acreage for 1990, 2000 and 2030 in three subregions of the Great Plains: Northern Plains (NP), Southern Plains (SP), and Mountain states (MT) (after USDA SCS 1987). The subregions are as defined in the text.

unincorporated cities and towns) of 2,500 to 50,000, then approximately 46% of the Nation's cropland occurs within this potential growth area and the SMSA counties (Gustafson and Bills 1984). Within the Great Plains, the only areas likely to see this growth outside the commuting zone are areas surrounding urban centers in Oklahoma and Texas. The dramatic increases in the small size beef operations in these states may foster a residential encroachment of rural areas. Obviously, population growth in the areas which currently contain 46% of the nation's cropland imply a stronger demand for the remaining 54% of cropland occurring in more rural areas.

The consequences of the projected idle cropland were not specified in the Appraisal analysis. Acres in cropland could be idled in a short- or long-term government programs. Past crop acreage control programs have returned large land areas to native or herbaceous vegetation with observable impacts on bird and mammal populations. The increase and decrease in pheasant numbers in South Dakota were significantly related to Soil Bank acres (Erickson and Wiebe 1973). Although farmers in South Dakota had placed 3 million acres of wheat and feed-grain land in annual set-aside retirement in 1972, twice the South Dakota Soil Bank acreage, pheasant numbers did not reach the high population levels seen during the Soil Bank. Of 8,106 ac. surveyed, over 65% of the retired cropland acres were without vegetative cover (Erickson and Wiebe 1973). In study examining pheasant populations in Minnesota, Nebraska, North Dakota, and South Dakota, Schrader (1960) reported that pheasant rates of increase were greater in counties where more than 5% of the cropland was retired into permanent vegetative cover.

The short-term nature, either 1 year or 10 years, of acreage control programs does not allow for the development of the potential natural community, thus favoring animal species that are associated with early successional stages. Once the contract period ended, most of the Soil Bank acres were plowed under (Bartlett and Trock 1987). And, as was shown above, cropland fallow, no vegetative cover, has been used to meet crop set-aside requirement. Thus, the ultimate use, with or without vegetative cover, the length of the contract period, and the relationship of the set-aside land to the total land use in the area affect the impact government programs have on wildlife.

The projected idle cropland could be converted into another use, such as grazing or urbanland. Conversion of cropland to range or pasture might reverse the trend of increased fragmentation of natural communities whereas conversion to urbanland would accentuate this trend (Brady, in press). Conversion of cropland to permanent vegetative cover has the beneficial effects of providing food, cover, and shelter for some wildlife species. Wild turkey populations can benefit from land use practices such as rotation grazing systems, and deferred pastures. However, smaller farms and ranches in Texas, particularly under the economic conditions of the 1970's, were dependent on intensive land use and could not afford the habitat management programs on larger ranches (Gore 1973).

The Appraisal projections indicated regional shifts in the land used in crop production (fig. 8). Incorporated into this

projection was the Conservation Compliance measure of FSA. This subtitle requires that farms with highly erosive land engage in conservation farming practices on lands remaining in crop production as a condition of eligibility for participation in commodity programs. The definitions of conservation farming practices are still evolving, as are the rules for the kinds of land for which conservation plans must be developed (Dicks and Reichelderfer 1987).

Given the market price and cost conditions facing producers of major field crops, participation in commodity programs poses a strong financial incentive to develop conservation plans. A study of effects of conservation compliance provisions for a representative cotton farm in the Southern High Plains of Texas found that the farmer has no choice but to participate in government programs (Lippke et al. 1986). Without participation, the typical farm studied could not be expected to survive for five years. Continuation of the commodity program, but without the conservation compliance provisions, would give the farm a very good chance of survival. Farms with light soils, for which conservation plans include establishing windstrips, have their chances for survival greatly reduced. In general, required conservation compliance provisions were found to threaten the livelihood of such farms. At the same time, the commodity programs are necessary to keep the farms financially solvent.

The definition of conservation practices will impact other resources besides soil erosion. While nesting cover could be maintained by chemical fallowing on cropland (Benson 1977), this practice may also create problems for water quality or native fauna. The commonly used contact herbicide, paraquat, has been shown to increase mortality and impair growth in mallard embryos when applied at field application rates (Rodgers 1983). The impacts on non-targeted species are greater under the increasing use of broad spectrum chemicals (National Academy of Science 1982). The advantage of the pesticides currently in use is their relatively short half-life, although the initial toxicity on native fauna may be great (National Academy of Science 1982). In a recent study of no-till winter wheat impacts on nesting ducks, Duebbert and Kantrud (1987) reported no pesticide-related mortality with no-till. Clearly, the debate is not over.

Conclusions

Environmental, ecological, and economic factors affect the distribution and success of government crop programs within the Great Plains and across the nation. Great Plains cropland is removed from production because it has the lowest profit margin per acre and much variability of returns. Single objective programs, such as soil conservation, are ineffectively served by retiring Great Plains cropland as soil erosion is often greater in other regions of the nation. Within a region such as the Great Plains, the distribution of acres in a set- aside program, such as the CRP, affects soil erosion level and wildlife habitat. Long-term (10-year) diversions have greater potential for improving wildlife habitat than do the annual diversions and associated conservation compliance measures. An evaluation of the CRP for wildlife requires not only an examination of the planting, but of the land use within which the plantings are set. There are 12.9 million acres of the Great Plains in CRP now -- projected to go to 20 million. Five times this amount of cropland is projected to be out of production in the Great Plains by 2000. This potential shift in land use could overwhelm any impact the CRP acres would have in the Great Plains.

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A Prospectus for Research Needs Created by Passage of the Conservation Reserve Program

John E. Mitchell and Gary R. Evans[1]

Abstract.--The CRP will result in the payment of billions of dollars to convert highly erodible land to a permanent vegetative cover. For the Program to succeed, changes in land use must remain in place after the 10-year payment period ends. This paper outlines research needs to aid in reaching towards such a goal.

Soil erosion is recognized as a major problem that threatens food production on a global scale and results in profound environmental difficulties (Mabbutt 1980). In the United States, food production is not presently limiting; nonetheless, potential productivity has been declining at an alarming rate due to soil erosion (Crosson 1985). Besides reducing productivity, soil erosion causes expensive off-site environmental disturbances to industry, agriculture and wildlife (Piemental et al. 1987).

The costs to society of farming highly erodible cropland are expressed primarily in terms of off-site effects, and these sum to billions of dollars annually (Clark 1985). Therefore, the Conservation Reserve Program (CRP), a provision of the Food Security Act (FSA) of 1985 and described earlier in these Proceedings, may represent a logical societal investment in the long term. It is not, however, the first attempt by the federal government to control erosion in such a manner.

The CRP is, in some ways, commensurable with the Soil Bank of the late 1950s and 1960s, which contained its own conservation reserve program. The Soil Bank, authorized in the Agricultural Act of 1956, was established more to adjust supplies of agricultural commodities than to encourage soil conservation practices (Held and Clawson 1965), and land did not have to be highly erodible to qualify. However, farmers could participate in the conservation reserve provisions of the Act by setting land aside. Many of the practices were identical to those now being implemented under the CRP.

During the Soil Bank era, USDA paid $2.6 billion, amounting to nearly $9 billion in 1987 dollars, to subsidize farmers for converting cropland to permanent grass or tree cover. At its zenith in 1960, contracts covered 28.6 million acres under the program. Supposedly, this acreage was out of crop production to stay; however, such an outcome, unfortunately, did not occur. After the last contracts expired in 1972, most land seeded to grass went back into grain production during the agricultural upturn and return to more traditional price support programs that followed (Rasmussen 1982).

Land converted to permanent cover under the CRP is, ostensibly, less likely to revert to annual crop production again because of the conservation compliance provisions of the 1985 FSA. To do so without an approved conservation plan would deny farmers eligibility for other USDA commodity support programs. Nonetheless, when information germane to various management alternatives is lacking, farmers cannot be expected to make the decisions, rationale or not, envisioned by the authors of the Farm Bill.

If a large proportion of the land in the CRP does go back into annual cropping after the 10-year rental period, the direct cost to the government for the Program's failure will be substantial. Outlays are easily expected to exceed $5 billion over the first 5 years, according to some observers.[2] These costs could escalate even more if average rental payments increase as less marginal lands are included in the Program to reach acreage goals. Therefore, a high priority should be placed upon finding ways to maintain these highly erodible lands under permanent cover.

Policy makers will be primarily responsible for creating conditions conducive to maintaining land under permanent cover of grass or trees after the 10-year rental payments end. To make informed decisions, they need to understand the economic and ecological ramifications of these land conversions on all levels of society within the United States. Such knowledge will allow them to (1) recommend possible changes in existing legislation and regulations pertaining to the CRP and (2) prop-

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erly educate and inform participants and the general public about the Program.

The purpose of this paper is to briefly describe some of the gaps within the knowledge base available to agricultural policy makers and propose a research strategy for filling those gaps where knowledge is most urgently needed.

Knowledge Gaps

Ecology

Successional dynamics of natural communities have been studied in the Great Plains for more than 75 years (Shantz 1923). However, models of natural succession do not adequately explain what happens after grain fields are seeded to perennial grass (Bement et al. 1965). For example, Wilson and Briske (1979) found that blue grama *(Bouteloua gracilis)* could not be reestablished on some sites it dominated previously unless the soil remained moist during critical periods of seedling establishment. Such climatic conditions occur with extremely low frequency, and do not fit statistical parameters associated with the initial floristics model commonly used to interpret natural secondary succession.

During the soil bank and dust bowl eras, millions of acres of cropland were planted to grass. Some of these pastures remain in place, including lands purchased by the federal government and placed within the national grassland system. Consequently, an excellent opportunity exists to study successional dynamics of seeded plant communities by evaluating these old fields. In some cases, however, it may be difficult to retrieve the data necessary to determine initial conditions.

The successful establishment of perennial grass on cropland is a risky undertaking in the Great Plains. Some factors, such as weather and insect outbreaks, cannot be mitigated; however, recent advances in seeding technology have lessened the risk considerably (USDA Forest Service 1982). Seeding trials have provided a myriad of data on the suitability of different species and cultivars throughout the region (McGinnies et al. 1983, Eck and Sims 1984).

Seedbed preparation techniques, on the other hand, comprise an area of relative uncertainty (Hart and Dean 1986). In the Great Plains, a mulch of some kind is needed to retard wind erosion, retain soil water and moderate soil temperature (Vallentine 1971), but specific requirements based on research findings are generally lacking. Also, where established procedures are known, they frequently are not followed or are modified without a sound ecological basis.[3] Consequently, criteria for approved seeding plans under CRP vary among states and areas within states. For example, the phytotoxic effects of allelopathic agents associated with wheat stubble on germination and growth (Guenzi and McCalla 1962) provide the basis for restricting its use as a cover crop in some areas. However, definitive quantitative research has not been conducted to describe causal relations and limitations of these secondary plant products under actual field conditions. Treatment effects have been too difficult to isolate in complex soil-plant systems (Mandava 1985).

The CRP provides opportunities for the development of wildlife habitat. Although wildlife biologists know a great deal about habitat creation and improvement (Yoakum et al. 1980), additional research is needed. Farmers with small holdings may find that management practices in surrounding areas have a larger or controlling influence on wildlife populations than those they implement. As patches of habitat suitable for a given wildlife species become more dense, their synergistic effect may be substantial. The study of spatially dynamic systems will require new theory or innovative adaptation of existing theory. For example, foresters have recently looked at the minimum critical size of ecosystems (Burgess and Sharpe 1981) using MacArthur and Wilson's (1967) theory of island biogeography, a concept which could have application in wildlife management.

Expanded research is needed to evaluate advances in livestock grazing systems in relation to wildlife habitat quality on the High Plains. Historically, cattle have been managed on the basis of continuous grazing systems because various rotation systems were presumed to be ineffectual in improving range condition or animal performance (Herbel 1971). During the past decade, however, interest in short duration grazing systems has proliferated along the Great Plains (Heitschmidt et al. 1982, Kirby and Parman 1986). Although a few workers have reported how grazing systems affect a single upland game species (Hammerquist-Wilson and Crawford 1981), information remains seriously lacking.

Shelterbelts may also be planted on lands under provisions of the CRP. On the Great Plains, their most common observed use is for protection of farmsteads, even though they have been shown to reduce soil erosion, enhance crop production, provide wildlife habitat, and manage snowdrift location (Tinus 1976). To date, only a few hundred acres have been devoted to windbreaks under CRP, a fact that serves as a barometer of their perceived net value to those entering the Program. This disparity between actual and perceived value must logically result from a lack of available information. Unfortunately, research into establishment, management, and renovation of shelterbelts has decreased at just the time it may have been needed most.

A great deal of research has been conducted on soil losses from land under various climatological, physiographic, and management alternatives (Wischmeier and Smith 1978), including rangeland (Blackburn 1980). However, additional research is needed if watershed models are expected to accurately predict actual erosion from rangeland (Foster et al. 1981). Information on soil loss rates from reclaimed cropland is necessary if policy makers are to monitor how successfully the CRP actually reduces erosion.

At the watershed level, little is known about the effects of trapping windblown soil from adjacent fields on rangeland.

[3]Personal communication from Pat O. Currie, Research Leader, USDA-ARS Livestock and Range Research Station, Miles City, Mont.

Bartling (1987) showed a negative correlation between depth of deposited loess and blue grama production, but suggested other factors, such as increased temperature or high levels of soil phosphorus, may be causal. In addition, the role of grasslands as a possible depository and reservoir for vectors, insects and windblown pathogens has received no substantive research.

Economics and Sociology

Much of the ecological and physiological research dealing with functional knowledge gaps has not considered costs of their associated management practices. Although products of basic research cannot be limited by economic viability, applied research must be designed so that both costs and benefits can be assessed. New and innovative techniques, such as using drip irrigation systems to establish and maintain shelterbelts, will only be accepted if they can be shown to be cost effective.

The constraints of cost sharing provided by the CRP appear to be an area of concern for participating farmers (personal communication, attendees of this Symposium). Weed control provisions requiring repeated or expensive herbicide applications which are not adequately funded may result in failure to achieve desired objectives. On the other hand, future rental payments to new participants may become large enough to balance inadequate cost sharing as less marginal lands are included to reach acreage goals.

Any program that infuses large amounts of capital into a region can be expected to cause substantial perturbations to local and regional economies. The CRP is still too new to evaluate many of these effects, although some are discussed earlier in this Proceedings. Indication exists that capital is being distributed unequally in parts of Colorado and Texas, causing hardships within certain segments of local economies (Reichenberger 1987). The effect of CRP on qualified and non-qualified land prices has some potential to destabilize local economies. It should be imperative to at least monitor the economic structure of high- and moderate-impact areas using input-output models.

The CRP has already had an adverse effect on the winter forage supply in southeastern Colorado as a result of the loss of crop residue from fields placed into permanent grass cover and withdrawn from livestock use.[4] This will require ranchers to set aside pastures normally grazed during the growing season to compensate for this lost winter-early spring forage base. The economic ramifications of such a seasonal shift in forage supply have not been studied, but could have both short- and long-term significance.

In parts of Texas, farmers have learned that land managed for wildlife habitat can provide higher net income than solely from livestock or, at times, farming (Payne et al. 1987). However, conditions in Texas, such as a lack of public land, large areas suitable for big game habitat, and substantial amounts of discretionary income, are different from those across much of the Great Plains. Research on demand for wildlife and wildland recreation resources, including various kinds of wildlife, is needed by those assessing various options on CRP lands of all kinds, including shelterbelts (Dwyer 1980). Such information is needed to develop land use strategies involving wildlife as a resource base.

Besides knowing the economic effects of CRP during the period in which rental payments are being made, policy makers need prognoses of impacts on local economies after the contracts expire. At a regional level, expiration of CRP contracts could exert a substantial perturbation on the range livestock industry when millions of acres are potentially released for grazing or other forage uses including hay. The effects of this excess capacity in the range land base should be given close analysis or the stability of range livestock interests could be substantially perturbed.

Societal issues, although closely tied to economic considerations, form a unique area of research associated with the CRP. As previously discussed, policy makers failed to anticipate the response of farmers to the cessation of the Soil Bank Program; consequently, the federal government essentially lost several billion dollars. If those participating in the CRP are to be motivated towards continued land stewardship after the Program ends, their attitudes and behavior must be understood early enough to allow political decisions necessary to achieve such success (Napier and Forster 1982).

Socio-economic topics relating to the CRP are more than causal factors which affect agricultural policy. From a research perspective, the reverse is also true. That is, in order to adequately evaluate the range of opportunities open to policy makers in administering the 1985 FSA, the impacts of changes in macro-level agricultural policy on the CRP requires evaluation. Strategies to achieve national soil conservation objectives will depend greatly upon, and be limited by, the ideology of prevailing national policy. Hence, repercussions of possible changes in agricultural policy must be studied.

Proposed Research Strategy

Various state and Federal research agencies have demonstrated expertise in the topics outlined above. These include state universities and experiment stations; state fish and game and land management agencies; USDA Agricultural Research Service, Economic Research Service, and Forest Service; and USDI Fish and Wildlife Service. The USDA Soil Conservation Service (SCS), which is not a research agency, is the source of most information on past and present practices involving land use conversion from row crop agriculture to permanent cover, and would necessarily be involved in support of any major research program undertaken. Soil Conservation Districts, which have responsibilities for soil and water conservation at the local level, could provide practical input to research planning.

Professional societies also can provide leadership and assistance in a joint research program supporting CRP. For example,

[4] *Personal communication from E. T. Bartlett, Dept. of Range Science, Colorado State Univ., Fort Collins.*

the International Association of Fish and Wildlife Agencies has initiated a cooperative effort within its membership to monitor wildlife populations on some CRP lands. The Society for Range Management has formed a task force on the CRP to aid the SCS in undertaking a number of tasks at the request of the Chief of the SCS.

To be effective, a large scale research program should be placed under the auspices of a central organization. The USDA is probably best suited to establish priorities, acquire funding, and monitor research progress by participating organizations. It is not the purview of this paper to propose specific research topics or assignments; only to describe the need. If adequate funds are obtained to support the research needed to fill identified knowledge gaps, the return on investment will be considerable, perhaps exceeding 10 to 1. This assumes the need to reimplement another conservation reserve program for highly erodible lands that do return to crop production. If a research budget of $25 million resulted in keeping one-fourth of the lands presently under contract in permanent cover, the return would be on the order of 40 to 1. Such opportunities entreat a serious examination of the tradeoffs and strategies of a coordinated research program.

Conclusions

The dust bowl years of the 1930s provided a graphic lesson on the legacy of improper land management in the Great Plains. As a society, we should have realized the importance of soil as a basic resource which, once lost, cannot be replaced by any act of mankind. Despite the steps taken in erosion control on farmland, soil continues to be lost and in drought years, such as 1976-77, at rates comparable to that infamous period five decades ago (Lockeretz 1978). Even soil erosion from lands that are marginal for crop production has been shown to be highly detrimental in terms of off-site effects. Therefore, it is recognized that large areas of land now used for row crop agriculture should be taken out of grain production and put back under a permanent plant cover. Such an understanding justifies the recurring investments of public funds for land conversion, including the CRP. Given the risks associated with these programs in relation to the costs involved, research to fill ecological and socio-economic knowledge gaps affecting policy and management decisions is justified. A coordinated team effort, involving both federal and state agencies, as well as private interests, will be needed to establish and achieve specific research goals for the benefit of society.

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The Role of SCS and SRM in Implementing the Conservation Reserve Program

Wilson Scaling[1]

I commend all of you in the Society for Range Management's Colorado Section for your active role in addressing the future of lands going into the Conservation Reserve Program (CRP). SCS and other USDA agencies are very concerned about what happens to CRP land after the 10-year contract period. We are, of course, considering the conservation cover in plans that will help meet the long-term objectives of the producer. This kind of symposium is vital to ensure that the program works as well as possible -- that we are achieving our goals of soil and water conservation and of economic revitalization for American agriculture.

Your regional concerns are very important: The Great Plains region accounts for a large part of the CRP enrollment. And the range industry has a big stake in the outcome of the program. And, while we have regional concerns, we have to keep in mind a global perspective that Secretary Lyng talked about yesterday. We have to be mindful that agricultural production and related resource use in the United States are influenced by economic factors stemming from the agricultural and trade policies and activities of the world community more than at any other time in history.

Here at home, the CRP makes good sense in terms of economic strategy for agriculture -- indeed for all sectors of the economy:

- We're taking out of production the most highly erodible and most fragile lands, which also demand the most production inputs if cropped.
- Erosion reduction benefits of the CRP are cutting state and local public costs in terms of water quality, and cleanup of roads and waterways. And we still don't have the total picture as to these offsite benefits. But we suspect they are significant.
- Plant cover aids water conservation -- so critical to our Great plains watershed.
- Optimum plant cover put in place under the CRP stabilizes the soil, and benefits wildlife and the attractiveness of the landscape.

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- The program cuts commodity surpluses and helps agricultural production become market based.

The CRP can be a real boon to rural development in this country -- in the Great Plains and elsewhere:

- It can help preserve rural America, but not at the expense of agribusiness (that's why the 25% limit on a county's acreage allowed into the Reserve).
- And, it can help those farmers who are at the brink of disaster. One of the program's strengths is that putting land in the Reserve for 10 years can help those who are making the transition from agriculture to other enterprises.

I understand the deep concern surrounding the potential increase in grassland and its effects on the red meat industry and other parts of local economies in the Great Plains. But, I am also convinced that putting conservation cover on highly erodible and fragile lands is the best approach to long-term economic viability.

Here's what SCS is doing to make the best of CRP for the long term:

- We're giving the commitment to make it work.
- We're sitting down with other USDA agencies to discuss future policy affecting land coming out of the Reserve.
- We're providing technical expertise, as in the selection of plant materials. The Meeker Plant Materials Center here in Colorado is a prime example of federal, state, local, and private-sector cooperation.
- And, we're part of the Department's information and education team devoted to clarifying what CRP means to producers and communities. That effort includes reading out to limited-resource producers and Native Americans.

USDA cannot work alone and make the program a success. Our history shows that a strong cooperative partnership with state and local groups is what makes public conservation

programs the most effective and puts the most conservation on the ground. That is no less the case with the CRP.

I personally would like to see the Society for Range Management, and other professional organizations, play a major role in helping ranchers and farmers make wise decisions as to the disposition of CRP land after the 10-year contract period is up.

Here's my 7-point CRP challenge to the Society:

1. Help identify which land is best suited for use as range, and thus help to prevent adverse effects of the CRP on the range industry or on individual producers. Work with local organizations to determine which is most likely to be retained as range, based on (a) the quality of the land, (b) its proximity to established livestock facilities, and (c) the long-term management capabilities and interests of the operator.
2. Use your Society's resources to help educate and persuade operators with CRP land to make the correct decisions now so that the land will stay in grass after 10 years. For example, educate or re-educate grain producers who no longer produce grain but now have grass and range as a result of the CRP. Help them to establish, understand, manage, and maintain range for the highest economic return after CRP.
3. Help show the wildlife, water quality, and other benefits that result from permanent vegetative cover on these fragile, erodible lands.
4. Be a leader! Work closely with other organizations to build a consensus -- not just a group of single-interest decisions.
5. Encourage state and local hunting laws that allow CRP land to be maintained for hunting and thereby kept under protective cover.
6. Work with the Department and other agencies in identifying needed legislation, policy, and procedures to continue the benefits of the CRP on beyond 10 years.
7. And if you truly are interested in improving market conditions for the livestock industry, work with the Beef Council to dispel the 12 myths about red meat, which are:

    1. Beef is high in cholesterol.
    2. Beef is high in calories.
    3. Beef is high in saturated fat.
    4. The nutritional value of all meats is about the same.
    5. The nutritional value of the iron in beef is the same as the value of iron in vegetables.
    6. Beef is hard to digest.
    7. Diets recommended by health organizations should not include beef.
    8. Americans eat too much beef.
    9. Beef contains dangerous drug residues.
    10. Beef is frequently processed under unsanitary conditions.
    11. Beef has fallen out of favor with most Americans.
    12. Beef cattle use grain that could be used to feed the world's hungry.

    *Beef Industry Council

Thank you again for the leadership and initiative you've shown this week. I speak for all the SCS when I say that we appreciate your concern for the effectiveness of the CRP and for the well-being of the Great Plains.

Mitchell, John E., editor. 1988. Impacts of the Conservation Reserve Program in the Great Plains: Symposium Proceedings. [Denver, Colorado, September 16-18-1987] USDA Forest Service General Technical Report RM-158, 134 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

The Conservation Reserve Program, created in the Food Security Act of 1985, will place up to 45 million acres of cropland under permanent cover for 10 years. At some cost, it provides opportunities to reduce soil erosion, enhance wildlife habitat, stimulate components of the farm economy, and reduce commodity surpluses.

Keywords: Grass seeding, plant establishment, windbreaks, wildlife, rangeland, cropland, wetland, range ecology, farm policy, land conversion, rural sociology, agricultural history.

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky Mountains

Southwest

Great Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

United States
Department of
Agriculture

Forest Service

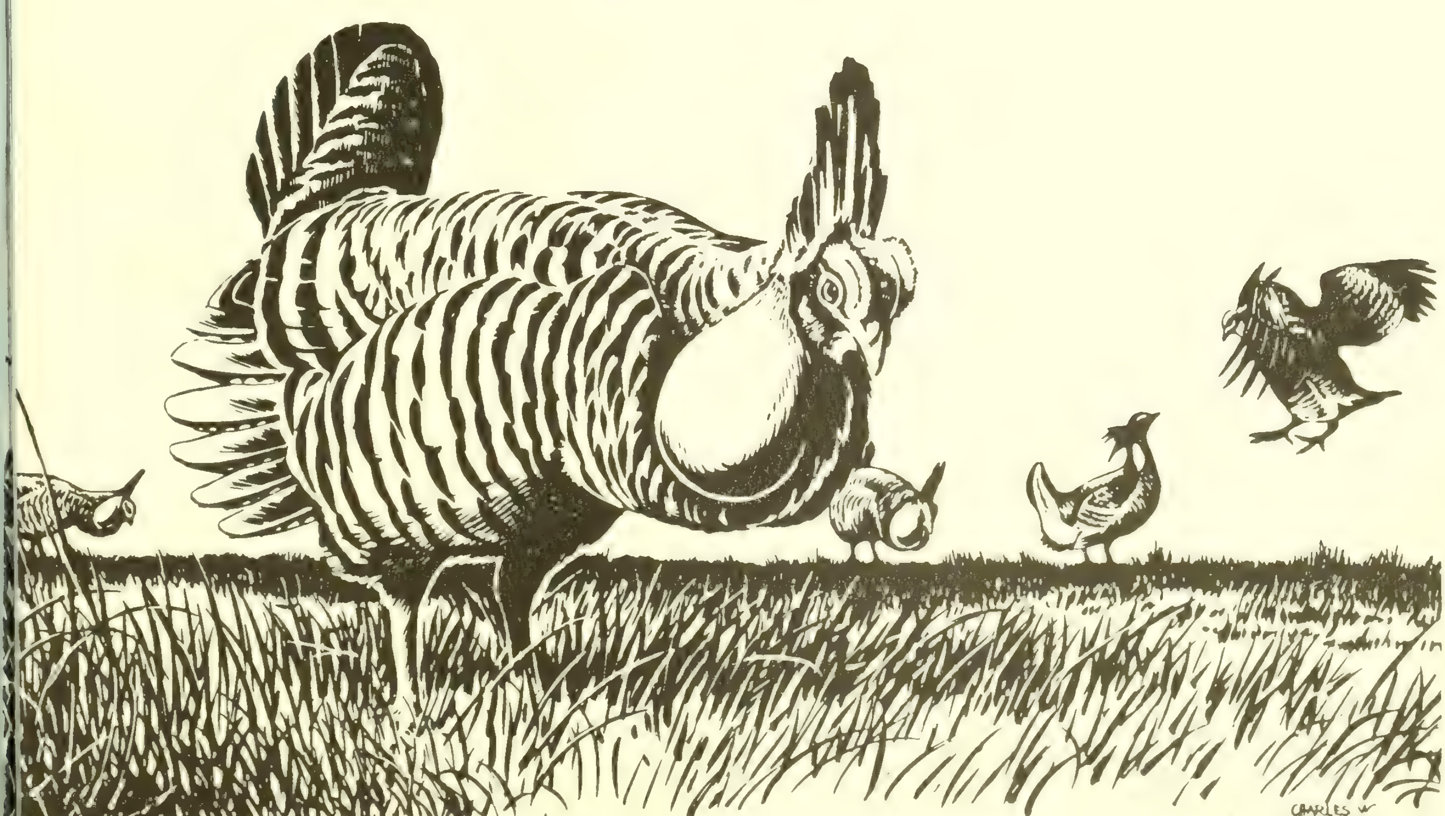
**Rocky Mountain
Forest and Range
Experiment Station**

Fort Collins,
Colorado 80526

**General Technical
Report RM-159**

Prairie Chickens on the Sheyenne National Grasslands

**September 18, 1987
Crookston, Minnesota**



Foreword

The greater prairie chicken (Tympanuchus cupido pinnatus), also known as the pinnated grouse, is a naturalized immigrant in the Dakotas. This species moved west in the 1880's from the east-central United States, when the Dakotas were under homestead settlement and grain was commonly planted adjacent to vast expanses of prairie.

The prairie chicken moved west as far as northwestern South Dakota, but is now absent from many parts of its newly adopted range. Populations have declined in 11 of 12 States, and completely disappeared in 6 States. However, populations have remained in areas of the Dakotas. These have become noteworthy in south-central South Dakota and southeastern North Dakota.

The prairie chicken population in southeastern North Dakota has centralized on the delta of the glacial river of the Sheyenne River, which drained into glacial Lake Agassiz. This delta was formed when the Sheyenne River carried overflow from glacial Lake Souris in north-central North Dakota to glacial Lake Agassiz. These events took place near the end of the Wisconsin Glacial Period some 10,000 to 12,000 years ago. This seemingly ideal habitat for the prairie chicken--sandy grassland with interspersed grain cropland--has perpetuated the immigrant and provided a subject for considerable research.

Research data on the prairie chickens of the Sheyenne Delta have never before been assembled in one place. The 17th Prairie Grouse Technical Conference was proposed as the setting to conduct the symposium on the "Prairie Chickens on the Sheyenne National Grasslands".

More than 100 people attended the 17th Prairie Grouse Technical Conference and "Prairie Chickens on the Sheyenne National Grasslands" Symposium, held September 15-19, 1987 on the campus of the University of Minnesota, Crookston. The conference and the symposium brought together researchers, educators, students, managers, and field technicians. The conference included a general session on all species of grouse, while the symposium centered on the "Prairie Chickens on the Sheyenne National Grasslands". These published proceedings document the symposium.

The proceedings of this symposium will serve as valuable reference for continued improvement in the management of the habitat of the prairie chicken. They will also provide further incentive for the Great Plains Agricultural Council to continue its promotion of similar symposia.

Ardell J. Bjugstad, Chairman
Dan Svedarsky, Co-Chairman
Tom Nichols, Co-Chairman

ABSTRACT

Bjugstad, Ardell J., tech. coord. 1988. Prairie chickens on the Sheyenne National Grasslands [symposium proceedings]. 1987 Sept. 18; Crookston, MN. Gen. Tech. Rep. RM-159. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 73 p.

These proceedings contain eight papers and two abstracts of papers presented at a special symposium arranged as a part of the 17th Prairie Grouse Technical Conference. The papers document and synthesize information gained over the past several years on prairie chicken ecology, habitats, and diets, and effects of cattle grazing.

USDA Forest Service
General Technical Report RM-159

June, 1988

Prairie Chickens on the Sheyenne National Grasslands

September 18, 1987
Crookston, Minnesota

Ardell J. Bjugstad
Technical Coordinator

Co-sponsors:

Great Plains Agricultural Council
Prairie Grouse Technical Council
Minnesota Prairie Chicken Society
University of Minnesota
USDA Forest Service

Rocky Mountain Forest and Range Experiment Station
Fort Collins, Colorado

Great Plains Agricultural Council Publication No. 123

Contents

Prairie Chicken Populations of the Sheyenne Delta in North Dakota, 1961-1987[1]

Jerry D. Kobriger, David P. Vollink, Michael E. McNeill, and Kenneth F. Higgins[2]

Abstract.--Prairie chickens (Tympanuchus cupido pinnatus) were first censused on the Sheyenne Grasslands in 1961. The population was extremely low in the 1960's, gradually increased in the 1970's, and reached a peak of 410 in 1980. Sufficient evidence exists to link the increase in numbers of prairie chickens on the grasslands from 1961 through 1987 to changes in land management, primarily the introduction of rotational grazing practices and prescribed burning of meadows.

INTRODUCTION

The Sheyenne National Grasslands, under administration of the United States Forest Service (USFS), is located in southeastern North Dakota about 30 miles from both Minnesota and South Dakota. There are 70,180 acres under Federal administration but 64,609 acres of private land are also included within the grassland boundary. These public lands were obtained by purchase in the 1930's under the Bankhead-Jones Farm Tenant Act.

The senior author first became aware of grouse on the Sheyenne Grasslands in September, 1963, at the Prairie Grouse Technical Council meeting in Nevada, Missouri when John Mathison presented a paper entitled "Prairie Grouse Habitat and Plans for Management on the Sheyenne National Grasslands". In 1963, when Mathison gave his report, 9 male prairie chickens had been counted on the Sheyenne Grasslands. The particulars of the paper are hard to recall, but in John's abstract he states: "Direct wildlife improvements and coordination with other resource management is being considered for wildlife". It sounds like up to this point in time that wildlife considerations were nil. He also stated that "all of the publicly owned land is in prairie which is grazed by livestock under special USFS permit. The native tall grass prairie has been largely replaced by intermediate and introduced species". The improvements that Mathison mentioned that would aid prairie grouse were: fencing to protect woody cover; planting of shrubs; and good grazing practices. Perhaps by the conclusion of this session today we will learn, after 24 years, if these were good recommendations and if they were actually carried out.

PRAIRIE CHICKEN CENSUS DATA

The first prairie chicken census actually occurred in 1961: 6 booming grounds were located; 2 were censused; and 5 males were counted. Lloyd Oldenburg, biologist for the North Dakota Game and Fish Department, filed a report on 13 April 1961 which stated: "on 12 April, 46 miles of transect were covered on which stops were located to effectively census 88 square miles". Oldenburg calculated a prairie chicken density of 0.5 birds per square mile, a low population but with potential for rapid increase, should habitat conditions become suitable. In his memo, Oldenburg noted that all grouse were observed within 1/4 mile of areas excluded from grazing and farming. He recommended fencing 40 acres per section to benefit all wildlife. It is interesting to note that Richard Flory, Wildlife Staff Assistant, USFS, who aided in the survey that year, recommended fencing only 10 acres per section for wildlife.

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[1] Paper presented at the Prairie Chickens on the Sheyenne National Grasslands Symposium, September 18, 1987, at the University of Minnesota, Crookston.

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David P. Vollink, North Dakota Game and Fish Department, Box 147, Lisbon, N.D. 58054.
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Kenneth F. Higgins, U.S. Fish and Wildlife Service, South Dakota Cooperative Fish & Wildlife Research Unit, Box 2206,Brookings, S.D. 57007.

Table 1. Prairie chicken census, Sheyenne Grasslands, North Dakota, 1961-70.

Ground Number	Year of Census 1961	1962	1963	1965	1966	1968	1969	1970
1	*	0	*			*	7	
2	*	*	*					
3	*	0						
4	1	1						
5	4	6	9	4	3	0	0	2
6	*	0	*		0	0		1
7		2						
8		*	*					
Total Males	5	9	9	4	3	0	7	3

* Booming ground was heard and plotted but not censused.

No counts were made in 1964 or 1967.

Census attempts were made in 1962, 63, 65, 66, 68, and 1969. During this period the highest counts were in 1962 and 1963 when 9 males were seen each year; none were seen in 1968 (Table 1). In 1970, 5 personnel helped conduct surveys on all or parts of 3 different mornings. Despite ideal conditions on 2 of the mornings, only 2 male prairie chickens were recorded; however, 1970 must have been a good production year because 1971 was the turning

Table 2. Prairie chicken census, Sheyenne Grasslands, North Dakota, 1971-80.

	Year of Census 1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Grounds Visited	6	15	20	17	25	29	33	31	48	49
Active Grounds Counted	5	12	14	14	23	20	24	22	36	39
Total Males	20	68	89	78	139	139	188	195	338	410
Males/ Active Ground	4.0	5.7	6.4	5.6	6.0	7.0	7.8	8.9	9.4	10.8

Table 3. Prairie chicken census, Sheyenne Grasslands, North Dakota, 1981-87.

	Year of Census						
	1981	1982	1983	1984	1985	1986	1987
Grounds Visited	29	37	40	28	43	22	39
Active Grounds Counted	17	28	34	26	27	22	24
Total Males	137	223	396	313	262	173	220
Males/ Active Ground	8.1	8.0	11.6	12.0	9.7	7.9	9.2

point in the spring male counts (Table 2). Three personnel worked the area in 1971, located 5 active grounds and 20 males. In 1972, 6 biologists counted 68 males on 12 grounds. The prairie chicken population continued to increase, reaching a peak in 1980 when 410 males were counted on 39 booming grounds.

The census effort has remained fairly constant since 1979 except for 1981. The prairie chicken population (males) has fluctuated between 410 and 173 (excluding 1981) (Table 3).

It is difficult to assess the true population numbers over the long term due to

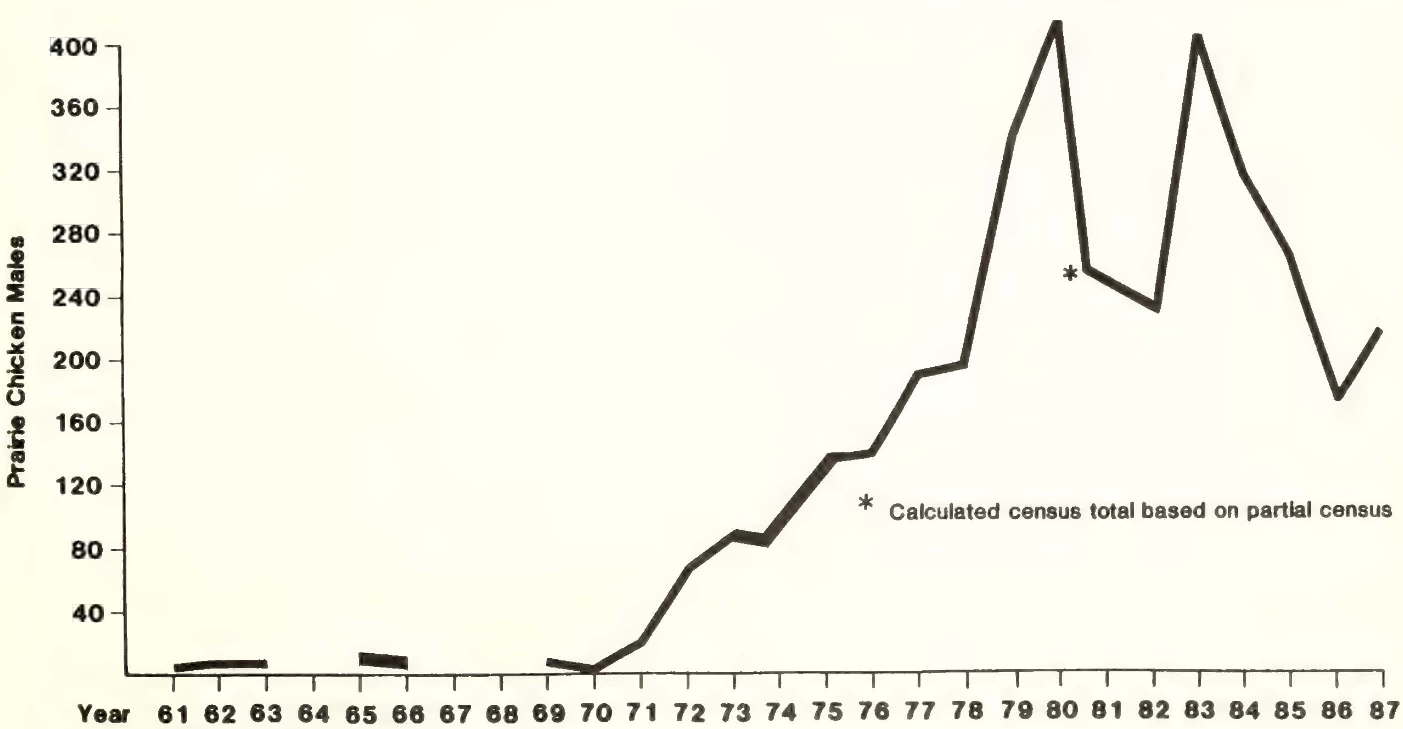

Figure 1. Male prairie chickens counted, Sheyenne Grasslands, North Dakota, 1961-1987.

incomplete census work, particularly during the early years. However, there is no doubt the population increased from 1961 through 1987 (Fig. 1). A significant positive relationship exists between males counted per year and year of census (Fig. 2).

At this point in time, it would do little good to dwell on the accuracy of population figures for the early years, it is sufficient to know that the population was very low. But, with better census effort and data from 1979 through 1987 (Fig. 3), the population trend has been downward, but not significantly so (Fig. 4). We do not think the downward population trend is cause for immediate alarm, but it is of concern. The population, compared to earlier census years, is still in good shape.

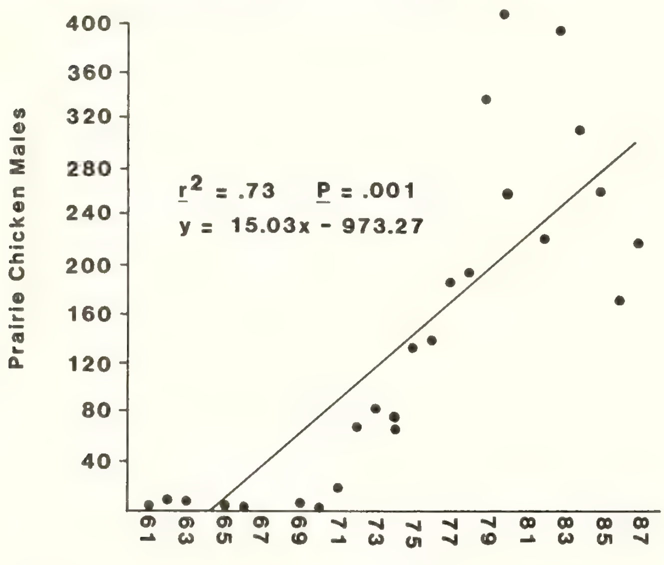

Figure 2. Linear relationship between total prairie chicken males counted and year of census, Sheyenne Grasslands in North Dakota, 1961-1987.

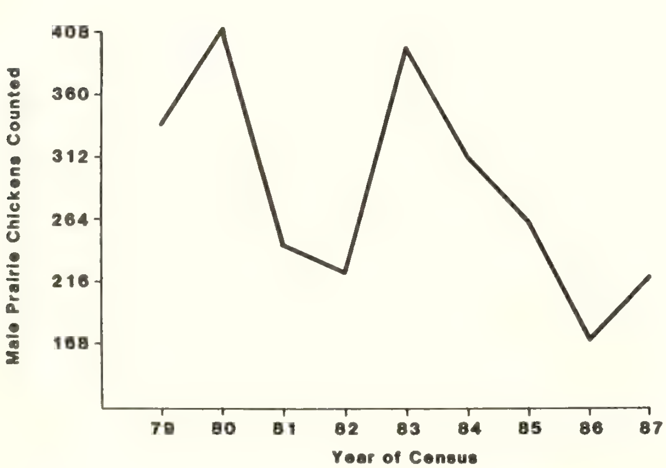

Figure 3. Male prairie chickens counted on the Sheyenne Grasslands, North Dakota, 1979-1987.

With this prairie chicken population, and with the interest shown in the area, as demonstrated by this symposium today, this trend can be reversed. The prairie chicken population in the Sheyenne grasslands is the only viable one left in North Dakota and the species is listed as threatened on the state list.

Manske and Barker (1981) estimated that approximately 100 square miles of potential prairie chicken habitat occurs in the Sheyenne National Grasslands. Densities of prairie chicken males in this area have ranged from 0.2 per square mile in 1961 to 6.2 per square mile in 1980 for potential habitat. We and many other biologists believe that the peak number of males (410) that was counted in 1980, was not the potential peak population that could be attained on the Sheyenne grasslands area. Westemier (1983) has stated that 100 prairie chicken males per square mile of nesting cover are realistic goals in Illinois. In North Dakota, sharp-tailed grouse (Kobriger and Oldenburg 1965) densities have reached about 18 males per square mile of total habitat. Thus, we believe a realistic goal for the Sheyenne Delta grasslands area would be 16 male prairie chickens per square mile of potential cover or double the estimated 8.2 males per square mile of occupied habitat in 1980.

LAND MANAGEMENT-PRAIRIE CHICKEN RELATIONSHIPS

A very apparent relationship existed between the number of male prairie chickens and the predominant type of land management being practiced on the Sheyenne Delta grassland area. The increase in the prairie chicken population between 1961 and 1987 is almost entirely attributable to changes in land management, primarily grazing practices (Fig. 5), because during the same period it was illegal to hunt prairie chickens and systematic predator control measures were not in practice. Thus, very little, if any, of the expansion in prairie chicken numbers was due to curtailment

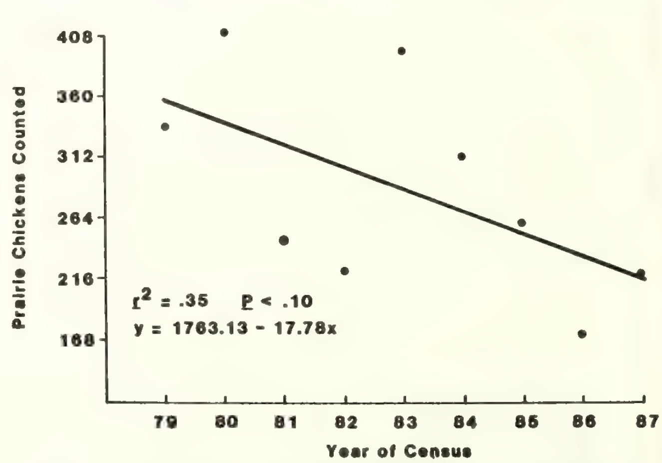

Figure 4. Linear relationship between total male prairie chickens counted and year of census, Sheyenne Grasslands, North Dakota, 1979-1987.

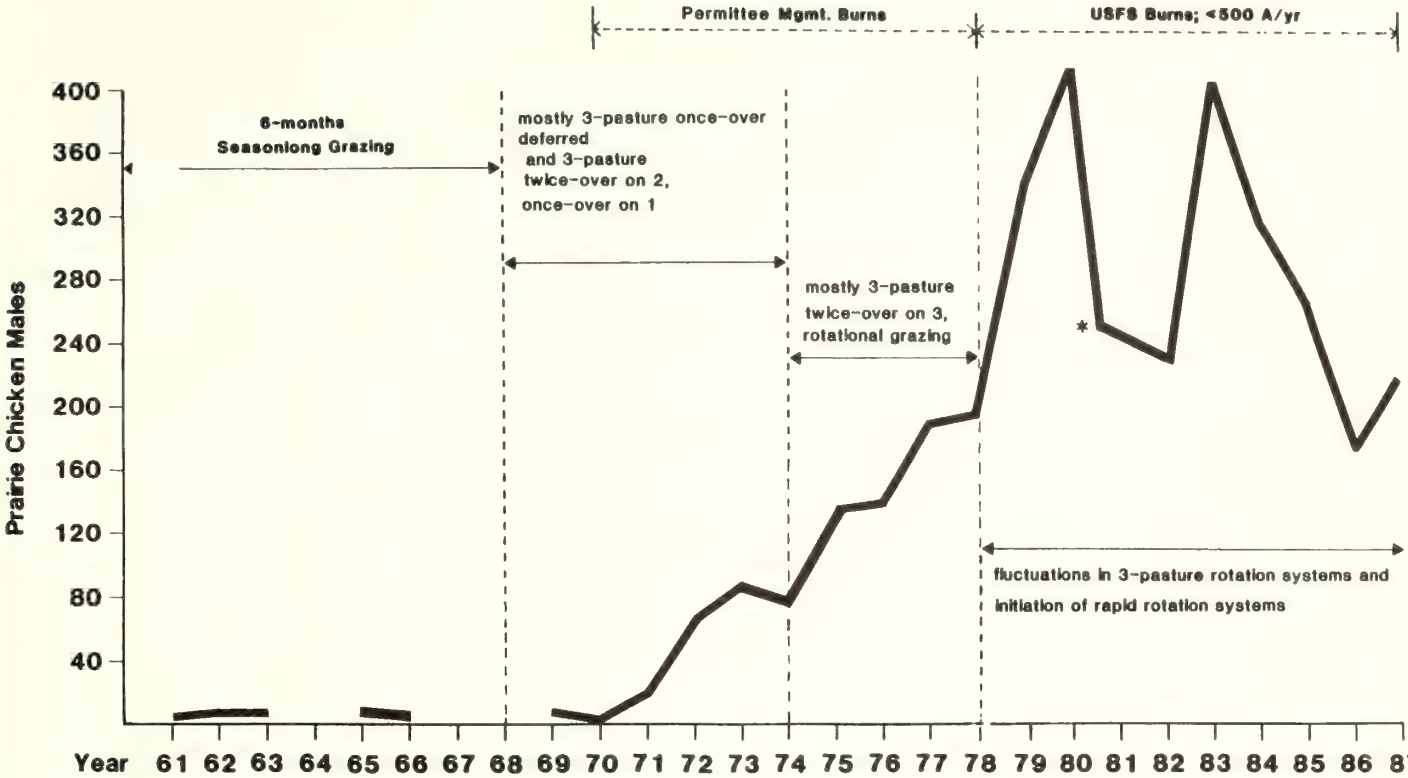

Figure 5. Land management relationships to prairie chicken males counted in spring during 1961-1987, Sheyenne grasslands, ND.

* 1981 count was estimated on the basis of partial survey
No burns in 1975 or 1980

of harvest or the elimination or control of predators by professional predator control agents. During 1961-1987, the amount of winter food supply in terms of corn and sunflower seeds increased but we have no direct evidence to indicate whether or not food was a limiting factor. However, the N.D. Crop and Livestock Reporting Service records for Ranson and Richland Counties indicate significant increases in sunflower and corn acreages from 1969 through 1986 and these acreages appeared to correlate with grouse numbers .

Seasonlong Grazing

The 56 allotments on the Sheyenne grasslands were managed with a "seasonlong grazing treatment" for 8 months duration during 1940-1954 and 6 months duration from 1955-1967. In 1967, cross-fencing was established on some allotments. When the Sheyenne grasslands were managed with seasonlong grazing, the prairie chicken population was apparently kept at the threshold of extinction ($\leq$ 10 males in total per year) (Fig.5).

3-Pasture Once-Over Deferred Rotation

Starting in 1968, some type of rotational herd management was initiated on several allotments and by 1974 approximately 63% of the allotments or 84% of the total land area was being managed with rotational grazing, primarily a "3-pasture once-over deferred rotation system". With this system, one herd was rotated once among the 3 pastures after approximately 45-60 days of grazing per pasture. Essentially, 2 of the 3 pastures were overgrazed with this system of herd rotation but 1 pasture retained some residual cover for the next spring.

The first noticeable increase of prairie chickens in early spring occurred in 1971 or during the 1968-1974 period (Fig. 5). The delay in prairie chicken response following the substantial reduction in seasonlong grazing in 1967 may have been due to the residual effect of seasonlong grazing on the habitat causing a delay in plant community response during 1968 and possibly even into 1969. Furthermore, the winter of 1968-1969 was one of extremely heavy snow cover and it may have affected food availability and subsequently the post-winter reproductive condition of female grouse. Thus, we believe there is good justifiable cause to imply that grouse production may have been delayed until the 1970 nesting season and these birds were subsequently censused in spring 1971.

However, the increase of prairie chickens during 1968-1974 cannot be singly attributable to the change in grazing practices, because in 1970 prescribed burning was also introduced as a grassland management practice on the same area (Fig. 5). The objective of the prescribed burning was mainly to reduce willows (Salix spp.) in the meadows and to induce better grazing utilization of the meadows (Barker 1983).

3-Pasture Twice-Over Rotation Systems

There are two types of 3-pasture twice over systems: 3-pasture twice over on 2-pastures, once on 1-pasture; and 3-pasture twice over on 3 pastures.

Between approximately 1971-1974, and again during 1979-1985, the primary grazing system was a "3-pasture twice-over on 2-pastures, once-over on 1-pasture deferred rotation system". This system increased the herd rotation on two of the pastures from a previous history of once-over to twice-over. Between 1971-1974 this system was used on about 28% of the area and between 1978 and 1979 it went from 5% to 36% and averaged about 41% of the area between 1979-1984.

Starting in approximately 1974, some of the grazing allotments were managed with a "3-pasture twice-over on 3 pastures". This system increased the herd rotation to every 28 days instead of the 45-60 days in the 3-pasture once-over rotation system. In this system, the herds are rotated twice over on 3-pastures. This system was increased in use on the grasslands from 1974 until 1978 when 54% of the area was managed with it.

Simultaneously in the same period, permittee burning and mowing of meadows had increased in practice, and as many as 5,000 acres were spring burned annually between 1 April and 20 May, except in 1975. There was no burning in 1975 because of a record high rain fall. With the implementation of the 3-pasture twice-over rotation systems in combination with meadow burning, the prairie chicken population continued to increase (Fig. 5).

Land Management Changes 1979-1987

Some significant changes in grazing systems practices and prescribed burning occurred between 1979 and 1987. In 1979 prescribed burning by permittees was curtailed and 3-pasture twice-over on 3-pastures rotational grazing was reduced from 40% to 10% of the area and this was replaced primarily by an increase in 3-pasture twice-over on 2-pastures, once-over on one-pasture, deferred rotational systems and smaller total acreages ($\leq$ 500 acres) being managed with prescribed burns by USFS.

About 1982, a type of "short-duration rotational system" was implemented on one allotment and by 1986 this system of grazing practice was being used on 4 allotments. With this system, cattle are moved every 12 days among 3 pastures. The grazing period varies from as few as 7 days to a maximum of 15 days. In some other allotments, a few seasonlong pastures were converted to either a 2 pasture twice-over rotation or to a 3-pasture twice-over deferred rotational system.

In addition to individual pasture capacities, two aspects of plant physiology are utilized in selection of a grazing duration. One is that the plant should not be stressed a second time after being grazed while it is trying to regrow. The second aspect is that the plant should be afforded ample time to regrow. On the Sheyenne National Grassland, the optimal time frames for these two aspects are thought to be 7-14 days of grazing followed with at least 25-30 days rest between grazing periods.

Along with erratic changes in land management practices from 1979-1987, there were also erratic fluctuations in the number of prairie chickens (Fig. 5). The prairie chicken population on the grasslands continued to increase until a peak of 410 displaying males in 1980 even though large management burns and the area being managed with 3-pasture twice-over rotational grazing systems were greatly reduced in 1979. Very probably, the continuance in prairie chicken population increases during 1979 and 1980 were still in response to the residual positive vegetation response from the former management practices. A large population decline in 1981 (39%) corresponds with the large change in grazing from the 3-pasture twice-over on 3-pasture rotation systems (40% to 10%) to the 3-pasture twice-over on 2-pastures, once-over on 1-pasture deferred rotation system (5% to 36%) and little change in the seasonlong grazing. After 1980, the erratic fluctuations in the prairie chicken population are unexplainable. The population fluctuations may have been natural, they may have been due to periodic changes in grazing management systems or to winter food availability, e.g. greater acreages of sunflowers and corn , or a combination of these. We would also like to point out that these changes occurred with minimal burning of meadows after 1978.

SUMMARY AND MANAGEMENT IMPLEMENTATION

The prairie chicken population on the Sheyenne grasslands was near extinction in the early 1960's at the same time seasonlong grazing was practiced on the whole area. The population dramatically increased in size following changes in grazing practices and the addition of prescribed burning of meadows. Since the burning of large acreages of meadows by permittees was curtailed and several changes

in grazing systems, including the addition of short duration rapid-rotation systems in some allotments during 1982-1987, the relationship between land management practices and the numbers of male prairie chickens during spring counts is confounded and largely unexplainable when the grasslands are evaluated in total. By the very fact that all males on several "booming grounds" disappeared during 1981-1987 instead of a reduction of a few grouse from all or most of the booming grounds suggests that the contributing effect may be on an allotment basis rather than an overall natural cause affecting the entire population or grasslands area.

This prairie chicken population is the only remaining viable population in North Dakota. Because of the importance of this population, we offer the following recommendations:

1) Censuses should be made of displaying prairie chicken and sharp-tailed grouse (Tympanuchus phasianellus) males and all booming and dancing grounds should be mapped accurately within allotments on an annual basis.

2) Annual records should be accurately maintained on the amount, season, type, and intensity of land management practices and the kind and age structure of animals within grazing herds.

3) Prescribed burning practices of meadows should be brought back, at least to the amounts that were being done in the mid-1970's including permittee burning efforts (approx. 5,000 acres per year).

4) We propose that strong consideration be given to an evaluation of the effects and differences between 3-pasture, twice-over on 2-pastures and once-over on 1-pasture rotational systems and 3-pasture, twice-over on all 3-pastures deferred systems on greater prairie chicken populations and habitats.

5) We recommend further evaluation of the prairie chicken population in relation to land management practices, including past records as well as in the future, particularly on an allotment and pasture basis. Annual records should also be kept on acreages of corn, sunflowers and other potential winter food crops in and adjacent to the Sheyenne grasslands.

6) And lastly, we recommend a deferment of implementation of "short duration" grazing systems on additional areas or allotments until proper evaluation has been made of their effects on native prairie vegetation and wildlife.

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Habitat Usage by Prairie Grouse on the Sheyenne National Grasslands[1]

Llewellyn L. Manske and William T. Barker[2]

Abstract.--Prairie grouse habitat usage was observed for six years. Spring and summer habitat usage was primarily in the upland and midland grassland habitat types. Habitat usage shifted during the fall and winter to cropland and associated tree shelterbelts. The switchgrass plant community was the primary concealment cover for nesting and roosting. Cropland and associated tree shelterbelts was the primary habitat during winter.

Habitat management for Greater Prairie Chicken (Tympanuchus cupido pinnatus) and Sharp-tailed Grouse (Pedioecetes phasianellus) requires knowledge of the relative habitat usage by the grouse during different seasonal periods and major activities. The purpose of this study was to determine, in relative terms, which habitat types were being used by prairie chicken and sharp-tailed grouse during spring, summer, fall and winter and for spring courtship, nesting, brooding and day and night roosting.

STUDY AREA

The north unit of the Sheyenne National Grasslands is between 46°21' and 46°40' north latitude and 97°10' and 97°30' west longitude in Ransom and Richland counties of southeastern North Dakota. The boundaries include 67,320 acres of federal land and 63,240 acres of privately owned land. The federal land is administered by the United States Department of Agriculture, Forest Service and managed in cooperation with the Sheyenne Valley Grazing Association. The federal land is managed under the multiple-use concept. The primary uses are grazing by beef cattle, wildlife, and dispersed recreation. The private land is managed for grazing by beef cattle, hay production, and suitable areas are farmed for livestock feed or cash sale of harvested commodities.

The region has a continental climate with cold winters and hot summers. Data from the McLeod Weather Substation (U.S. Dept. Com. 1973) show that the long term mean annual temperature is 41.9°F. January is the coldest month with a mean temperature of 7.7°F. July and August are the warmest months with mean temperatures of 70.9°F and 69.9°F, respectively. The long term mean annual precipitation is 19.6 inches with 79% occurring during the growing season, April through September. The frost free period averages 130 days beginning in mid May. Soil thaw is usually completed in the spring by 1 May (Jensen 1972).

The Sheyenne National Grasslands is located on a geologic formation known as the Glacial Sheyenne Delta. The delta was formed near the end of the Wisconsin Glaciation where glacial meltwater of the glacial Sheyenne River emptied into Glacial Lake Agassiz and deposited sands, clays and gravels. A layer of nearly impervious lake sediments is below the delta formation. This layer is responsible for the relatively high water table of the area.

The vegetation on the Sheyenne National Grasslands consists of native forest, woodland and grassland communities and non-native (cropland) replacement communities with associated cultivated and introduced plant species. The native plant communities have quantitatively been described by Nelson 1964, Hanson 1976, and Manske 1980.

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[1]Paper presented at the 17th Prairie Grouse Technical Conference and Prairie Chickens on the Sheyenne National Grasslands Symposium University of Minnesota-Crookston, Crookston, September 15-19, 1987.

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METHODS

Field observations of prairie grouse habitat use were made from foot survey routes with trained bird dogs and listening and visual survey routes with a vehicle. This study of habitat usage by prairie grouse was conducted from March 1975 through February 1981. Foot survey routes were made by walking or riding on horse back along selected routes accompanied by a pointing dog. The length of each survey walked or ridden and the acreage covered by the dogs were recorded. Vehicle survey routes conducted similarly to standard spring census listening survey routes (Grange 1948 and Kirsch 1956) were made by driving a vehicle along all passable roads and trails and stopping at ¼, ½ or 1 mile intervals and scanning surrounding areas for grouse with the aid of binoculars and spotting scope. Concentrated efforts to locate nests, broods and day and night roosts were made at appropriate times. Cable-chain drag method as described by Higgins, Kirsch and Ball (1969) and Higgins et al. (1977) was also used to locate nest sites. Habitat use data were collected during the spring census. Distance from center of spring display grounds to livestock watering facilities was measured each year. The habitat use survey routes were conducted in all available habitat types during each seasonal period of each year. All time periods of the day were sampled except from 11:00 p.m. to 3:00 a.m. All prairie grouse observations were recorded in field notes by species and by sex, if it could be determined. Number and estimated age of chicks were recorded for each brood. The data included in each observation was: location (cadastral and/or allotment and pasture), land use, habitat type, dominant plant species, date, time of day, weather conditions, and behavioral activity of the bird. The habitat use data was separated into four seasonal periods, Spring (1 April - 15 June), Summer (16 June - 31 August), Fall (1 September - 15 November), and Winter (16 November - 31 March). Visual obstruction of vegetation was sampled by the height-density method developed by Robel et al. (1970a) and modified by Kirsch (1974). Visual obstruction measurements (VOM) were presented in decimeters. One decimeter equals 3.9 inches.

A map of the habitat associations was constructed using a combined mapping technique to include the vegetation, soil and topographic characteristics. A general vegetation map was constructed by visual interpretation of homogeneous reflectance from two sets of Landsat-2 images taken on 6 May 1976 and 22 August 1976 and one set of Skylab photographs taken 12 June 1973. A general soil map was constructed from the General Soils Maps of Ransom and Richland Counties (1963) using homogeneous regions of similar soil textural class and general topographic relief. Soil characteristics for the soil series were taken from Thompson and Joos (1975). A general topographic map was constructed from the nine U.S. Geological Survey Topographic Quadrangle Maps (1960) of the area by combining homogeneous physiographic regions. These three general maps, vegetation, soil and topography, were field checked and combined to form one Habitat Association Map.

All vegetation within the boundary of the Sheyenne National Grasslands north unit were classified into eleven habitat types according to vegetative composition, soil characteristics and topography. These habitat types were grouped into four habitat associations. Plant species composition, soil and topographic characteristcs were quantitatively described by Manske (1980) and Manske and Barker (1981) for each habitat type and habitat association. Acreages of each habitat type and habitat association were determined by electronic planimeter (3 replications) and dot grid (2 replications) on aerial photographs taken in 1970 (Manske and Barker, 1981).

Prairie grouse habitat use index as developed by Robel et al. (1970b) (% of bird locations/% of study area) was used to indicate relative habitat use by prairie grouse. A habitat use index value greater than 1.0 indicated that prairie grouse selection for that habitat was greater than expected if the grouse exhibited no preference. A value less than 1.0 indicated habitat use at a level less than expected. A value of zero indicated avoidance of that habitat type.

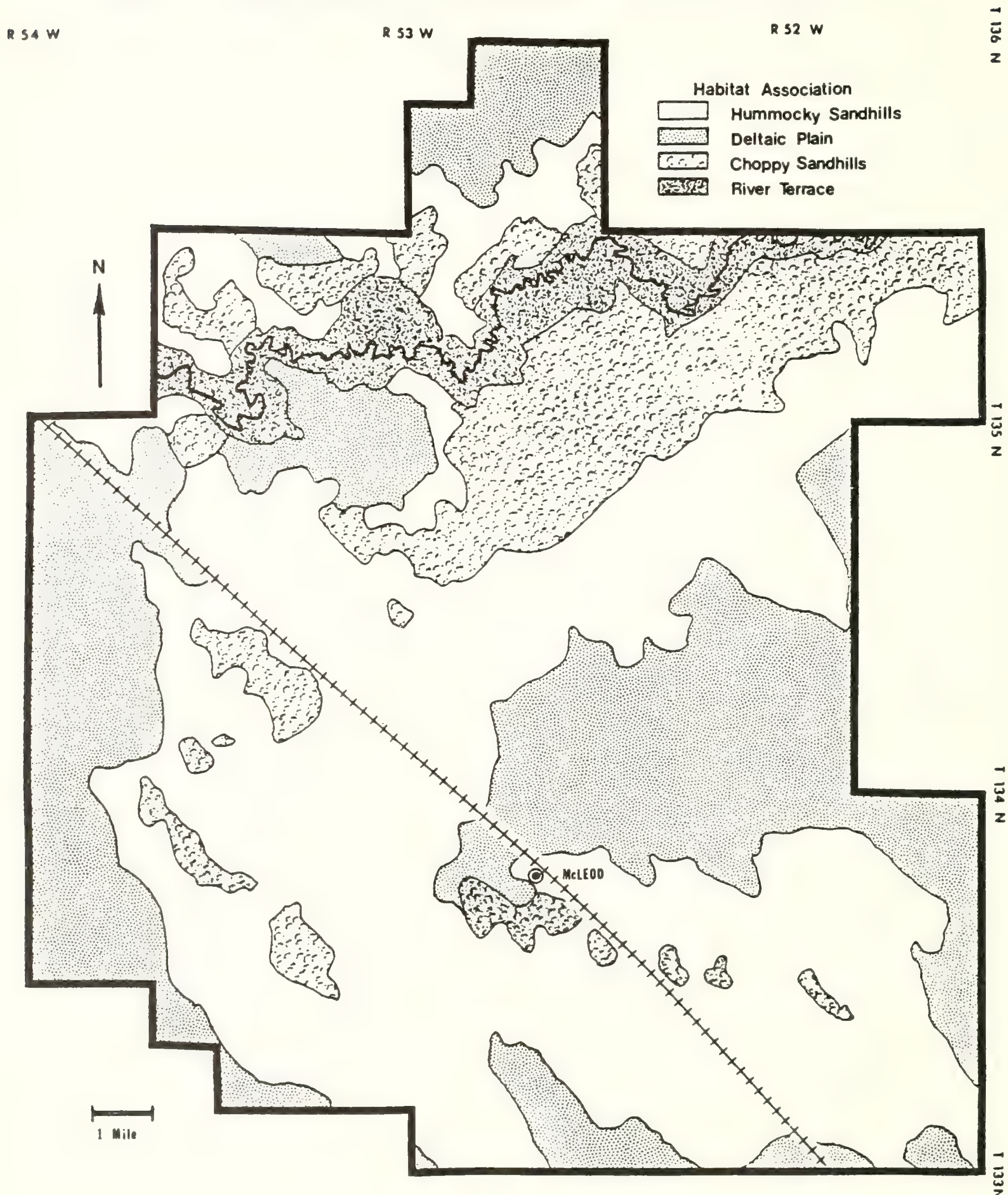
RESULTS AND DISCUSSION

Habitat Associations and Habitat Types

The vegetation on the Sheyenne National Grasslands was divided into eleven habitat types on the basis of similar plant species composition, soil type and topography. Eight habitat types consisted of native vegetation and three of replacement (cropland) vegetation. The habitat types of closely related characteristics and distribution were grouped into four habitat associations (fig. 1).

The Hummocky Sandhills Habitat Association consists of 65,494 acres, 50.16% of the Sheyenne National Grasslands. The topography is gently rolling and undulating hummocks (small hills) with relief usually 5 to 10 feet and slope 5 to 10%. The soils are primarily loamy fine sand with low available soil water. This habitat association is divided into four habitat types. The Upland Grassland Habitat Type exists on the summit and shoulder slopes of each hummock. The combined area is 34,389 acres (26.34%). The soils are loamy fine sand which are low in available soil water. The vegetation is the Bouteloua gracilis - Stipa comata - Carex heliophila mixed grass prairie community. The Midland Grassland Habitat Type exists on the back and foot slopes of each hummock with a combined

FIGURE 1. HABITAT ASSOCIATIONS ON THE SHEYENNE NATIONAL GRASSLANDS



area of 16,558 acres (12.68%). The soils are loamy fine sand with low to moderate available soil water. The vegetation is the Andropogon gerardi - Andropogon scoparius - Panicum virgatum tall grass prairie community. The Lowland Grassland Habitat Type exists on the foot and toe slopes and has an area of 12,737 acres (9.76%). The soils are fine sandy loam with moderate to low available soil moisture but with high soil moisture because of a high water table. The vegetation is the Carex lanuginosa - Calamagrostis inexpansa - Juncus balticus sedge meadow community. The Cropland Habitat Type exists on areas with generally low relief with characteristics of the midland habitat type. The combined area is small with 1,810 acres (1.39%). The soils are primarily loamy fine sand with low to moderate available soil water. The vegetation is primarily Zea mays and Medicago sativa. Associated with the cultivated land is 37 acres (0.03%) of planted tree shelterbelts.

The Deltaic Plain Habitat Association consists of 38,761 acres, 29.69% of the Sheyenne National Grasslands. The topography is nearly level with relief usually 1 to 2 feet and small areas of relief of 1 to 5 feet and slopes mostly less than 2%. The soils are primarily loam with high to moderate available soil moisture. The entire association has a high water table. This habitat association is divided into three habitat types. The Midland Grassland Habitat Type exists on areas that are slightly elevated with a total area of 14,476 acres (11.09%). The soils are loam to fine sandy loam and are high to moderate in available soil moisture. The vegetation is the Andropogon gerardi - Andropogon scoparius - Sorghastrum nutans tall grass prairie community. A very small area of less than 15 acres (0.01%) of Bouteloua gracilis - Stipa comata mixed grass prairie community exists within this midland habitat type on areas of slightly higher relief. The Lowland Habitat Type is located in the slight depressions in the landscape. The combined area is 5,387 acres (4.13%). The soils are loam with moderate to low available soil moisture. The vegetation is the Carex lanuginosa - Calamagrostis inexpansa - Carex spp. sedge meadow community. The Cropland Habitat Type is a large portion of this association because of the nearly level topography and good fertile soil. The combined area is 18,898 acres (14.47%). The soils are loam to fine sandy loam with high to low available soil moisture. The vegetation is primarily Zea mays, Medicago sativa and Helianthus annuus. Associated with the cultivated land is 402 acres (3.08%) of planted tree shelterbelts.

The Choppy Sandhills Habitat Association consists of 19,170 acres, 14.68% of the Sheyenne National Grasslands. The topography is very rough and choppy with relief usually 5 to 50 feet and slopes 10 to 20%. The soils are fine sand with very low available soil moisture. This habitat association is divided into two habitat types. The Upland Woodland Habitat Type exists on the slopes and depressions of the choppy topography and has a combined area of 12,269 acres (9.40%). The soil is fine sand with low available soil moisture. The vegetation is the Quercus macrocarpa - Populus tremuloides - Fraxinus pennsylvanica woodland community with a thin understory of grass, forbs and shrubs. The tree population varies from dense groves to scattered individual trees. The Open Grassland Habitat Type exists between the areas of dense groves and has a combined area of 6,901 acres (5.29%). The topography is rough and highly variable. The soil is fine sand with very low available soil moisture. The vegetation is the Bouteloua gracilis - Carex heliophila - Sporobolus cryptandrus mixed grass prairie community.

The River Terrace Habitat Association exists along the Sheyenne River and its spring fed tributaries. It consists of 7,135 acres, 5.46% of the Sheyenne National Grasslands. The topography is very level on the various alluvial terraces with a slope of 0.3%. The river channel has steep banks. The edge of the river valley has a very steep escarpment of 25 to 30 feet with a slope greater than 20%. The soils are silt loam with high available soil moisture. This association is divided into two habitat types. The Riparian Forest Habitat Type exists throughout the river terrace and river valley escarpment except for oxbow areas and areas cleared for farming. The area is 5,710 acres (4.37%). The soils are silt loam to silty clay with high available soil moisture. The vegetation is the Tilia americana - Ulmus americana - Fraximus pennsylvania forest community. Very small areas of sedge-cattail-willow wetland communities exist in the oxbows and along the river channel. The Cropland Habitat Type exists in areas that have been cleared of forest vegetation. The combined area is 1,425 acres (1.09%). The soils are silt loam with high available soil moisture. The vegetation is primarily Zea mays, Helianthus annuus and Medicago sativa.

Transportation Routes with associated right of ways have been constructed across the Sheyenne National Grasslands. Three categories of transportation routes were separated. The Railroad Transportation Route has 17.5 miles of track with 106 acres of right of way which is 0.08% of the Sheyenne National Grasslands. The Gravel Road Transportation Routes have 112 miles of road with 679 acres of right of way (0.52%). The Asphalt Road Transportation Route has 13 miles of road with 79 acres of right of way (0.06%).

Habitat Association Use

Prairie grouse habitat use for the four seasonal periods was primarily in two Habitat Associations, the Hummocky Sandhills and the Deltaic Plain (table 1). No prairie grouse habitat use was observed in the River Terrace

Table 1.--Habitat use index for prairie grouse during four seasonal periods of the habitat associations on the Sheyenne National Grasslands (SNG).

Habitat Association	% of SNG	Spring 1 Apr - 15 Jun Prairie Chicken	Spring Sharp-tailed Grouse	Spring Hybrid	Summer 16 Jun - 31 Aug Prairie Chicken	Summer Sharp-tailed Grouse	Fall 1 Sep - 15 Nov Prairie Chicken	Fall Sharp-tailed Grouse	Winter 16 Nov - 31 Mar Prairie Chicken	Winter Sharp-tailed Grouse
Hummocky Sandhills	50.17	1.89	1.98	1.99	1.78	1.79	0.73	1.62	0.36	0.34
Deltaic Plain	29.70	0.17	0.0	0.0	0.35	0.08	1.81	0.53	2.58	2.16
Choppy Sandhills	14.69	0.0	0.06	0.0	0.0	0.53	0.0	0.06	0.0	0.39
River Terrace	5.46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transportation Routes	0.66	0.0	0.0	0.0	0.0	0.0	14.57	2.89	8.00	19.55
(N) =		3642	958	117	638	350	780	210	3524	1248

Table 2.--Habitat use index for prairie grouse during four seasonal periods of the habitat types on the Sheyenne National Grasslands (SNG).

Habitat Association Habitat Type	% of SNG	Spring 1 Apr - 15 Jun Prairie Chicken	Spring Sharp-tailed Grouse	Spring Hybrid	Summer 16 Jun - 31 Aug Prairie Chicken	Summer Sharp-tailed Grouse	Fall 1 Sep - 15 Nov Prairie Chicken	Fall Sharp-tailed Grouse	Winter 16 Nov - 31 Mar Prairie Chicken	Winter Sharp-tailed Grouse
Hummocky Sandhills										
Upland Grasslands	26.34	1.64	2.48	1.95	1.18	1.36	0.55	0.76	0.14	0.31
Midland Grasslands	12.68	3.38	2.33	3.77	3.34	2.57	0.42	4.62	0.34	0.03
Lowland Grasslands	9.76	0.76	0.34	0.09	1.27	1.96	0.17	0.20	0.01	0.08
Cropland	1.36	0.97	0.61	0.0	2.65	1.89	11.12	0.70	6.11	5.07
Shelterbelts	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.81	32.05
Deltaic Plain										
Upland Grasslands	0.01	5.49	0.0	0.0	0.0	0.0	1897.44	190.48	295.12	0.0
Midland Grasslands	11.09	0.40	0.0	0.0	0.34	0.03	0.94	0.09	0.99	0.42
Lowland Grasslands	4.13	0.14	0.0	0.0	0.49	0.48	5.90	3.11	0.89	0.0
Cropland	11.39	0.96	0.0	0.0	0.41	0.0	0.0	0.0	3.68	4.28
Shelterbelts	3.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.56	3.51
Choppy Sandhills										
Upland Woodland	9.40	0.0	0.09	0.0	0.0	0.82	0.0	0.0	0.0	0.03
Open Grasslands	5.29	0.0	0.0	0.0	0.0	0.0	0.0	0.18	0.0	1.01
River Terrace										
Riparian Forest	4.37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cropland	1.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transportation Routes										
Railroad	0.08	0.0	0.0	0.0	0.0	0.0	68.91	0.0	59.24	161.26
Gravel roads	0.52	0.0	0.0	0.0	0.0	0.0	7.89	3.66	1.04	0.0
Asphalt roads	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(N) =		3642	958	117	638	350	780	210	3524	1248

Habitat Association. Prairie chickens did not use the Choppy Sandhills Habitat Association but sharp-tailed grouse did have some use in that Habitat Association during all four seasons. Generally, there was very little difference between the relative seasonal habitat use indeces of prairie chicken and sharp-tailed grouse.

Most of the prairie grouse activity was in the Hummocky Sandhills Habitat Association during spring and summer. Activity shifted to the Deltaic Plain Habitat Association during fall and winter. Sharp-tailed grouse shifted their activities from the Hummocky Sandhills Habitat Association to the Deltaic Plain Habitat Association later in the fall than prairie chicken and they shifted their activities back to the Hummocky Sandhills Habitat Association earlier in the spring than prairie chicken.

Habitat Type Use

Prairie grouse used a wide diversity of habitat types in each seasonal period and their relative habitat usage varied with the activity and seasonal period (table 2). Habitat usage during spring was primarily the Upland and Midland Habitat Types of the Hummocky Sandhills Habitat Association. Birds active in spring courtship rituals used areas of short native vegetation primarily on Upland and Midland Habitat Types with areas of taller vegetation adjacent or near. Birds not actively displaying during courtship used areas with taller vegetation primarily the Midland Habitat Type. Prairie chickens continued to feed on agricultural residue in the Cropland Habitat Types of the Deltaic Plain and Hummocky Sandhills Habitat Associations during early spring. Sharp-tailed grouse fed in the Cropland Habitat Type of the Hummocky Sandhills Habitat Association but did not use the Cropland Habitat Type of the Deltaic Plain Habitat Association during spring.

Summer habitat use was principally in the Hummocky Sandhills Habitat Association with all available habitat types selected. Prairie grouse disbanded into small groups or singles after spring courtship. Several male grouse continued to stay near display ground areas for a large portion of the summer. Hens were very mobile and used a wide variety of habitat types. Shrubs on the Midland and Lowland Habitat Types were used for cover and shade during the hot portions of summer. Areas with alfalfa (Medicago sativa) cropland were used for feed and cover.

Fall was a period with several changes. Hens left their broods which broke up and dispersed. Small flocks of adult and juvenile birds would gather on or near fall display grounds. These small flocks were very mobile and would travel several miles during a day. Habitat use shifted from primarily grassland vegetation to cropland. This shift in habitat usage was earlier for prairie chicken than sharp-tailed grouse.

Winter was a stressful period for prairie grouse. During severe weather, small flocks joined together and formed packs (flocks larger than 60 birds). Activities of these large flocks centered around cropland and adjacent shelterbelts, primarily in the Deltaic Plain Habitat Association. A very small amount of winter activity was conducted on grassland habitats of the Deltaic Plain and Hummocky Sandhills Habitat Associations. Spilled grain along transportation routes and in cropland and crop residue from harvested cropland were the primary sources for high energy winter food. Spilled wheat along the railroad right of way was used by most large flocks for food during late fall and winter. Trees in shelterbelts were used for cover and their buds, fruit and samaras used for food. Standing corn (Zea mays) and sunflowers (Helianthus annuus) were used for food when snow covered the spilled grain and other crop residue.

Display Ground Habitat

Prairie grouse spring courtship display grounds were primarily located on Upland and Midland Habitat Types on the Hummocky Sandhills Habitat Association (fig. 2 and table 3). A few prairie chicken display grounds were located on the Deltaic Plain Habitat Association. No sharp-tailed grouse display grounds were on the Deltaic Plain Habitat Association. No prairie chicken or sharp-tailed grouse display grounds were located on the Choppy Sandhills or River Terrace Habitat Associations.

Livestock tended to graze vegetation near some watering facilities to a shorter height than vegetation away from water. Distance from center of display ground to nearest livestock watering facility was measured for 176 prairie chicken and 87 sharp-tailed grouse display grounds. One hundred eighteen (67.1%) prairie chicken and 48 (55.2%) sharp-tailed grouse display grounds were less than 1500 feet from livestock water. Mean distance was 601 feet for prairie chicken and 569 feet for sharp-tailed grouse. Fifty-eight (33.0%) of the prairie chicken grounds were further than 1500 feet from livestock water. Twenty of these grounds had been mowed the previous year. Thirty-six had not been mowed of which 31 were restricted to the Upland Habitat Type. Only five (2.8%) of the prairie chicken display grounds had member male birds displaying on the Midland Habitat Type that had not been mowed the previous year and was greater than 1500 feet from livestock water. No prairie chicken males displayed on unmowed Lowland Habitat Types that were greater than 1500 feet from water.

Thirty-nine (44.8%) of the sharp-tailed grouse display grounds were further than 1500 feet from livestock water. Eleven of these grounds had been mowed the previous year.

FIGURE 2. PRAIRIE GROUSE DISPLAY GROUNDS ON THE SHEYENNE NATIONAL GRASSLANDS-1980

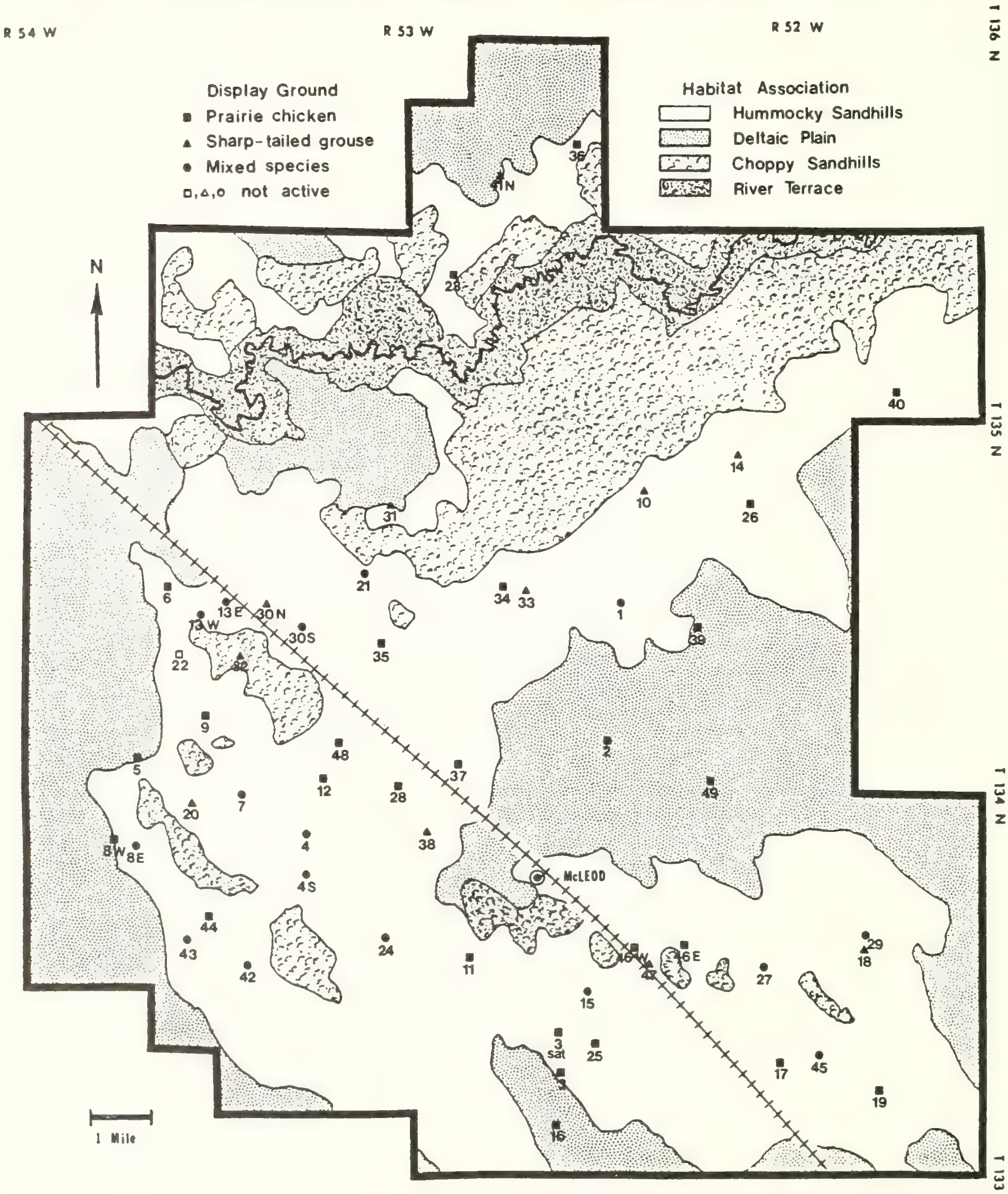


Table 3.--Habitat use index for spring courtship display grounds used by prairie grouse on the Sheyenne National Grasslands (SNG).

Habitat Association Habitat Type	% of SNG	Prairie Chicken	Sharptailed Grouse	Hybrid
Hummocky Sandhills				
Upland Grasslands	26.34	1.90	2.76	1.93
Midland Grasslands	12.68	2.56	2.15	3.72
Lowland Grasslands	9.76	0.99	0.0	0.0
Cropland	1.36	0.0	0.0	0.0
Shelterbelts	0.03	0.0	0.0	0.0
Deltaic Plain				
Upland Grasslands	0.01	131.58	0.0	0.0
Midland Grasslands	11.09	0.40	0.0	0.17
Lowland Grasslands	4.13	0.32	0.0	0.0
Cropland	11.39	0.08	0.0	0.0
Shelterbelts	3.08	0.0	0.0	0.0
Choppy Sandhills				
Upland Woodlands	9.40	0.0	0.0	0.0
Open Grasslands	5.29	0.0	0.0	0.0
River Terrace				
Riparian Forest	4.37	0.0	0.0	0.0
Cropland	1.09	0.0	0.0	0.0
(N) =		228	88	53

Twenty-eight had not been mowed of which 23 were restricted to the Upland Habitat Type. Five (5.75%) of the sharp-tailed grouse display grounds had member male birds displaying on the Midland Habitat Type that had not been mowed and was greater than 1500 feet from livestock water. No male sharp-tailed grouse displayed on the Lowland Habitat Type.

Vegetation for prairie grouse courtship display needed to be short. The plants that were present on the Upland Habitat Type were of short stature and acceptable to prairie grouse for courtship display activity with or without mowing and grazing management. Vegetation on the Midland and Lowland Habitat Types was generally too tall and unacceptable for courtship display activity unless it had been mowed the previous year or grazed short which occurred near some livestock watering facilities.

Concealment cover adjacent or near spring display grounds was considered to be important and 181 prairie chicken and 87 sharp-tailed grouse display grounds were evaluated for availability of concealment cover. Good concealment cover was considered to be vegetation with mean 100% VOM of greater than 1.5 decimeters (Manske and Barker, 1981 and Higgins and Barker, 1982). Respectively, 72.9% and 80.5% of the spring display grounds with prairie chickens and sharp-tailed grouse had very good concealment cover adjacent or very near. Courtship display areas with less than good concealment cover were 14.9% and 12.6% for the prairie chicken and sharp-tailed grouse, respectively. The remaining courtship display areas, 12.2% and 6.9% with prairie chickens and sharp-tailed grouse, respectively, had very poor or no concealment cover near the grounds. Most of the display grounds, 87.9% of the prairie chicken and 93.1% of the sharp-tailed grouse, had some concealment cover adjacent or near. Spring courtship display ground habitat appears to be a combination of short vegetation for display purposes and adjacent or very near areas with good cover for concealment.

Nest Habitat

Nineteen prairie grouse nest sites were located during this study. Eleven were prairie chicken and eight were sharp-tailed grouse nests. Six prairie chicken and six sharp-tailed grouse nests had completed clutches. Five prairie chicken and two sharp-tailed grouse nests had only partially completed clutches. Two prairie chicken nest scrapes were located with the hens present. Nine prairie chicken and eight sharp-tailed grouse nests were found in native grassland vegetation. All seventeen of these nests were in the Midland Grassland Habitat Type of the Hummocky Sandhills Habitat Association (table 4). Switchgrass (Panicum virgatum) was the dominant species at all of the nest sites in

Table 4.--Habitat use index for nest site locations used by prairie grouse on the Sheyenne National Grasslands (SNG).

		Prairie Chicken			Sharptailed Grouse		
Habitat Association Habitat Type	% of SNC	Full Clutch	Partial Clutch	Nest Scrape	Full Clutch	Partial Clutch	Nest Scrape
Hummocky Sandhills							
Upland Grasslands	26.34	0.0	0.0	0.0	0.0	0.0	0.0
Midland Grasslands	12.68	3.58	1.43	1.43	5.91	1.97	0.0
Lowland Grasslands	9.76	0.0	0.0	0.0	0.0	0.0	0.0
Cropland	1.36	0.0	0.0	0.0	0.0	0.0	0.0
Shelterbelts	0.03	0.0	0.0	0.0	0.0	0.0	0.0
Deltaic Plain							
Upland Grasslands	0.01	0.0	0.0	0.0	0.0	0.0	0.0
Midland Grasslands	11.09	0.0	0.0	0.0	0.0	0.0	0.0
Lowland Grasslands	4.13	0.0	0.0	0.0	0.0	0.0	0.0
Cropland	11.39	0.80	0.80	0.0	0.0	0.0	0.0
Shelterbelts	3.08	0.0	0.0	0.0	0.0	0.0	0.0
Choppy Sandhills							
Upland Woodlands	9.40	0.0	0.0	0.0	0.0	0.0	0.0
Open Grasslands	5.29	0.0	0.0	0.0	0.0	0.0	0.0
River Terrace							
Riparian Forest	4.37	0.0	0.0	0.0	0.0	0.0	0.0
Cropland	1.09	0.0	0.0	0.0	0.0	0.0	0.0
(N) =		6	3	2	6	2	0

native vegetation except for one sharp-tailed grouse nest where spiraea (Spiraea alba) and Kentucky bluegrass (Poa pratensis) were dominant species and switchgrass was subdominant. Two prairie chicken nests were found in alfalfa (Medicago sativa) of the Cropland Habitat Type. No sharp-tailed grouse nests were found in cropland. No prairie grouse nest sites were located in the Choppy Sandhills or River Terrace Habitat Associations.

Nest sites were characteristically completely covered by vegetation. Sides and top concealment at nests had very dense residual and growing vegetation. The mean 100% visual obstruction measurements (VOM) from six prairie chicken and eight sharp-tailed grouse nests at nest center was 2.9 ± 1.2 decimeters for prairie chicken nests and 2.6 ± 0.9 decimeters for sharp-tailed grouse nests. Some nest sites had a pathway through the vegetation where the hen passed in or out. The mean height-density at the 100% VOM of nest habitat within four meters of the nest site was 2.5 ± 1.0 decimeters for prairie chicken and 2.4 ± 0.6 decimeters for sharp-tailed grouse. There was no difference between prairie chicken and sharp-tailed grouse nesting habitat ($P>0.05$). The range in measurements for the 100% VOM for nest habitat was 1.5 to 3.5 decimeters. The 1.5 decimeter level at the 100% visual obstruction measurement (VOM) was considered from these data to be the minimum level for good nest habitat for both prairie chicken and sharp-tailed grouse. Prairie chicken and sharp-tailed grouse nest habitat was the switchgrass portion of the Midland Habitat Type of the Hummocky Sandhills Habitat Association with mean 100% VOM of 1.5 decimeters or greater. Prairie chicken also nested in alfalfa cropland.

Brood Habitat

Fifty-four prairie chicken and twenty-eight sharp-tailed grouse broods were located. Prairie grouse broods were very mobile and traveled over a considerable amount of area. Prairie chicken used all the available grassland habitat types and alfalfa cropland of the Hummocky Sandhills and Deltaic Plain Habitat Associations (table 5). Sharp-tailed grouse broods used the grassland habitat types of the Hummocky Sandhills Habitat Association and the Lowland Habitat Type of the Deltaic Plain Habitat Association. Sharp-tailed grouse broods also used the Upland Woodland Habitat Type of the Choppy Sandhills Habitat Association. These sharp-tailed grouse broods used the areas of shrubs and young trees on the edge of groves. No broods were located within the groves of mature trees. Prairie chicken broods did not use the Habitat Types in the Choppy Sandhills Habitat Association. Prairie chicken and sharp-tailed grouse broods did not use the Habitat Types of the River Terrace Habitat Association.

Table 5.--Habitat use index for prairie grouse broods on the Sheyenne National Grasslands (SNG).

Habitat Association Habitat Type	% of SNG	Prairie Chicken	Sharptailed Grouse
Hummocky Sandhills			
Upland Grasslands	26.34	1.27	1.56
Midland Grasslands	12.68	3.12	2.34
Lowland Grasslands	9.76	1.12	1.58
Cropland	1.36	1.41	0.0
Shelterbelts	0.03	0.0	0.0
Deltaic Plain			
Upland Grasslands	0.01	0.0	0.0
Midland Grasslands	11.09	0.46	0.0
Lowland Grasslands	4.13	0.62	0.69
Cropland	11.39	0.56	0.0
Shelterbelts	3.08	0.0	0.0
Choppy Sandhills			
Upland Woodlands	9.40	0.0	1.17
Open Grasslands	5.29	0.0	0.0
River Terrace			
Riparian Forest	4.37	0.0	0.0
Cropland	1.09	0.0	0.0
(N) =		54	28

Areas of short vegetation that had been mowed and grazed with adjacent areas of dense residual and growing vegetation were used considerably as feeding areas. The dense cover was used mainly for escape cover and loafing but very little for feeding. Broods usually used areas that had relatively high amounts of forbs and shrubs. These areas usually provided good canopy cover and relatively open understory. The percentage of broods observed in woody vegetation consisting of short shrubs was 47.3% of the prairie chicken and 51.7% of the sharp-tailed grouse broods. Most of the broods observed in the Upland Habitat Type, 93.7% of the prairie chicken and 81.8% of the sharp-tailed grouse broods, were in woody vegetation. The mean 100% VOM for Upland, Midland and Lowland Habitat Types used for brood cover was 1.6, 2.2, and 1.9 decimeters, respectively. The mean 0% VOM for the three habitat types was 3.6, 6.3, and 5.7 decimeters, respectively.

Prairie grouse brood habitat was a wide diversity of plant communities and height-densities. Generally broods were associated with vegetation with relatively larger amounts of forbs and short shrubs that provided good canopy cover and relatively open understories.

Night and Day Roost Habitat

Prairie grouse spent a considerable amount of time on ground roosts. They were on night roosts from dusk to dawn and on day roosts for a large portion of the day between morning and evening feeding periods. Roosting activity occupied the greatest amount of time in the life of a prairie grouse.

Prairie grouse night roost sites with the birds present were primarily in the Midland and Lowland Habitat Types of the Hummocky Sandhills Habitat Association during spring, summer and fall (table 6). The switchgrass portion of the midland grassland community was more important for night roosting than the upper portion. Night roost habitat shifted to Cropland and adjacent shelterbelts during winter. Some night roosting activity was continued in the midland grassland community with switchgrass in the winter. Tree shelterbelts were very important for night roosting in winter. This shelterbelt habitat included the rows of planted trees on the edge of cropland and also small areas of volunteer willow (Salix spp.), cottonwood (Populus deltoides) and/or aspen (Populus tremuloides) that were located in or near cropland. Trees provided some protection from the winter weather and deeper snow drifts developed in or near trees. Prairie grouse often burrowed into these snow drifts to roost at night. Most snow burrows were found in snow that

Table 6.--Habitat use index for prairie grouse night roost sites on the Sheyenne National Grasslands (SNG).

Habitat Association Habitat Type	% of SNG	Spring 1 Apr - 15 Jun	Summer 16 Jun - 31 Aug	Fall 1 Sep - 15 Nov	Winter 16 Nov - 31 Mar
Hummocky Sandhills					
Upland Grasslands	26.34	0.20	0.0	0.0	0.07
Midland Grasslands without switchgrass	12.68	0.10	0.0	1.17	0.14
Midland Grasslands with switchgrass	12.68	4.57	6.12	5.70	1.94
Lowland Grasslands	9.76	3.64	2.30	1.33	0.0
Deltaic Plain and Hummocky Sandhills					
Cropland	12.75	0.0	0.0	0.0	2.61
Shelterbelt	3.11	0.0	0.0	0.0	12.41
(N) =		76	49	54	57

was 12 inches or greater in depth. Snow drifts also tended to accumulate on the back and foot slopes on the lee side of hummocks in the grassland habitats. Prairie grouse also used these snow drifts to make burrows for night roosting.

The mean 100% visual obstruction measurements (VOM) for night roost sites was 1.9 ± 0.4 decimeters with a range from 1.5 to 2.2 decimeters. From these data, it was considered that 1.5 decimeters was the minimum level for good night roost habitat. This was the same as the minimum level determined for prairie grouse nesting habitat.

Prairie grouse day roost sites with the birds present were primarily in the Midland Grassland with switchgrass Habitat Type of the Hummocky Sandhills Habitat Association during spring and fall and primarily in the Upland and Lowland Habitat Types during summer (table 7). In summer, day roosts were associated with shrubs. Summer day roosts were mainly in lead plant (Amorpha canescens) in the upland and willow (Salix spp.) in the lowlands. Shrubs provided shade from the hot sun and good canopy cover in the summer. No day roost sites were found in the winter.

The mean 100% visual obstruction measurements (VOM) for day roost sites was 1.5 ± 0.4 decimeters with a range from 1.1 to 1.9 decimeters. The 100% VOM values were lower for day roosts than night roosts. Day roost sites characteristically had one of the four sides with very low vegetation. The birds head was at the side with low vegetation and the pile of feces developed at the opposite side. Mean 100% VOM for the three high sides of day roost sites was 1.9 decimeters.

Night roosting habitat was primarily the switchgrass portion of the Midland Habitat Type of the Hummocky Sandhills Habitat Association with mean 100% VOM of 1.5 decimeters or greater. During winter, night roosts were primarily in snow burrows. These snow burrows were located in areas where snow accumulated to 12 inches or greater in depth. Day roosting habitat was primarily the switchgrass portion of the Midland Habitat Type of the Hummocky Sandhills Habitat Association with mean 100% VOM of 1.1 decimeters or greater. Shrubs on the Upland and Lowland Habitat Types of the Hummocky Sandhills Habitat Association were used during the summer.

SUMMARY

The Hummocky Sandhills Habitat Association was the primary spring and summer prairie grouse habitat and the Deltaic Plain Habitat Association was the primary winter habitat. All of the grassland and cropland habitat types of the Hummocky Sandhills and Deltaic Plain Habitat Associations were used by prairie chicken and sharp-tailed grouse during some seasonal period of the year and should be considered as valuable prairie grouse habitat. The switchgrass portion of the Midland Habitat Type of the Hummocky Sandhills Habitat Association was by far the primary grassland habitat used by prairie chicken and sharp-tailed grouse on the Sheyenne National Grasslands. It was used for concealment cover during spring courtship. It was the only native grassland habitat selected for nesting. It was one of the major brood habitats. It was the primary night roosting habitat and an important day roosting habitat. The Cropland and associated tree shelterbelt Habitat Type was the primary prairie grouse habitat used in winter. The Cropland Habitat Type was used by prairie grouse for the source of high energy food from spilled grain, crop residue and unharvested

Table 7.--Habitat use index for prairie grouse day roost sites on the Sheyenne National Grasslands (SNG).

Habitat Association Habitat Type	% of SNG	Spring 1 Apr - 15 Jun	Summer 16 Jun - 31 Aug	Fall 1 Sep - 15 Nov	Winter 16 Nov - 31 Mar
Hummocky Sandhills					
Upland Grasslands	26.34	0.23	3.16	0.0	0.0
Midland Grasslands without switchgrass	12.68	0.0	0.0	0.0	0.0
Midland Grasslands with switchgrass	12.68	7.10	0.0	7.89	0.0
Lowland Grasslands	9.76	0.0	1.71	0.0	0.0
Deltaic Plain and Hummocky Sandhills					
Cropland	12.75	C.0	0.0	0.0	0.0
Shelterbelt	3.11	0.0	0.0	0.0	0.0
(N) =		10	6	23	0

standing row crops that they needed during the winter.

Management for prairie chicken and sharp-tailed grouse habitat should consider all available Habitat Types of the Hummocky Sandhills and Deltaic Plain Habitat Associations as important. Habitat types of the Choppy Sandhills and River Terrace Habitat Associations were not selectively used by prairie grouse and should be managed for purposes other than for prairie grouse. Two habitat types were more important to the prairie grouse than the other habitat types. These two habitat types were the switchgrass portion of the Midland Habitat Type of the Hummocky Sandhills Habitat Association and the Cropland and associated tree shelterbelts Habitat Type. The Midland Habitat Type should be manipulated by mowing or burning on a 5 or 6 year cycle to maintain high quality habitat. Portions of the Lowland Habitat Type should be manipulated by mowing and burning annually to draw grazing pressure away from the Midland Habitat Type. A conscious effort should be made by state and federal agencies to provide unharvested high energy food on the Cropland Habitat Types for use by prairie grouse during winter.

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A Method for Trapping Prairie Grouse Hens on Display Grounds[1,2]

John E. Toepfer[3], Jay A. Newell[3], and John Monarch[4]

Abstract: This paper describes a method for trapping prairie grouse hens on display grounds. The basic principle of the trap is a drift fence which funnels visiting hens into traps. The trap has been used successfully in at least 6 states and 2 provinces and on 4 species of prairie grouse. This method is less expensive and less disruptive than rocket or cannon nets.

INTRODUCTION

One of the most difficult and time consuming aspects of studying prairie grouse is capturing hens for marking and radio-tagging. Rocket and cannon nets placed on the display grounds have been used but they are cumbersome, and if used too often may disrupt normal breeding activities. This paper details a simple, inexpensive method for trapping hens on display grounds and if used properly creates only a minor disturbance to the displaying cocks.

The basic principle of this trap is that of a drift fence placed on the display ground. It's basic concept is not new since similar traps have been used to capture a wide variety of birds (Wilbur 1967 and McClure 1984). The "cloverleaf" trap (Dorney and Mattison 1956) used the same principle to capture ruffed grouse hens and their broods. Mussehl (1960) and Tomlinson (1963) used drift fences and funnel traps to capture blue grouse on the breeding grounds.

METHODS

This trapping system consists of a series of traps and wire leads placed to intercept hens as they walk across the display grounds. Two systems of deploying the leads were used: (1) a circle and (2) a "W" (Figs. 1 and 2). The circle was initially developed by John Monarch and associates to capture Columbian sharptail hens (*Tympanuchus phasianellus columbianus*). The circle system consisted of a series of 5 chicken wire leads and traps placed around the dominant cock, thereby intercepting and trapping hens as they visited the display ground for breeding (Fig. 1). One or more of the traps in this system should have a funnel opening facing the center to capture hens as they leave because some hens will jump the wire to get near the dominant cock. Placement of the leads is critical in the circle system because if it does not encircle the dominant cock, hens will walk by or around the leads.

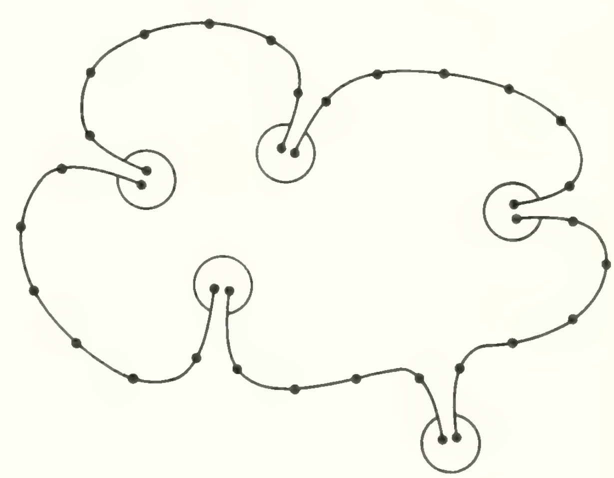

Figure 1.--Circle system of deploying traps and wire leads to capture sharptail hens.

Greater prairie chicken (*Tympanuchus cupido pinnatus*) cocks on booming grounds are more widely spaced than sharptails. Consequently the circle method does not cover enough of the booming ground to intercept hens. The circle system, also requires knowing the location of the dominant cock, which will limit trapping early in the

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[2]Contribution No. 2144 from Montana Agric. Exp. Stn.
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[4]Pittsburg and Midway Coal Company, Denver.

booming season. In order to cover more of the booming ground and trap earlier in the season Toepfer and Newell developed the "W" method of deployment (Fig. 2).

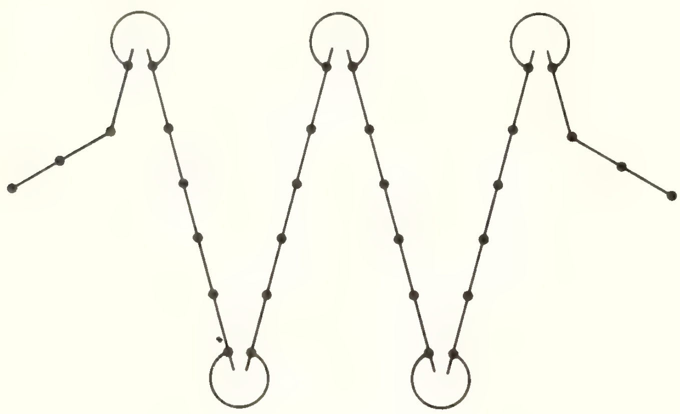

Figure 2.--"W" system of deploying traps and wire leads to capture prairie grouse hens.

The "W" consisted of 5 or more chicken wire leads oriented perpendicular to the path of visiting hens with funnel traps at the ends (Fig. 3). Trapping success was enhanced when the general movement patterns of hens were observed before placing the trap. Movement of hens varied between booming ground and often changed from day to day necessitating some adjustments in the positioning of the leads. Frequently the best location for the "W" was across the center of the display ground. The avantages of the "W" are that it covers more of the display ground and it can be effective when placed across the center of the display ground prior to observing the movement of hens.

Wire leads and traps were the same for both methods of deployment, and consisted of 18-24 inch, 1 inch mesh chicken wire. The number and length of the leads in the "W" system varied with the size of the booming ground. Five leads, 50-75 feet long, were usually used. The chicken wire leads were supported with metal or wooden stakes, although metal rods woven through the wire were the best. Early in the season a hammer was necessary to pound stakes into the frozen ground and a vice grips pliers was necessary to remove the stakes. Rigid chicken wire (1 inch mesh, 16-18 gauge) was used for leads so the cocks did not bend them over when using them for perches.

Catch traps were made of separate 8-10 foot long by 2 feet wide lengths of 2 x 2 inch or smaller mesh welded wire turned into a horseshoe-shaped coil with the two ends forming an entrance approximately 6 inches wide (Fig. 3). Larger traps can be used, but removing trapped birds becomes more difficult. Wire leads were fastened to the trap entrances so the leads went partway

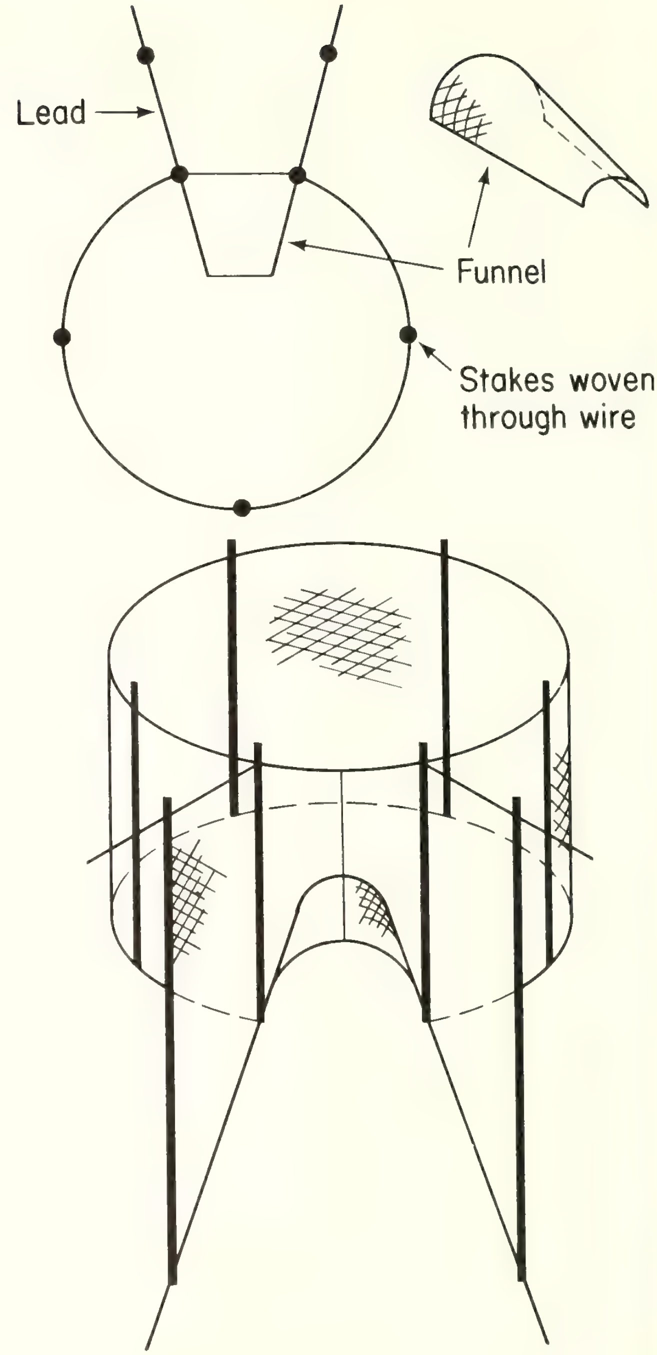

Figure 3.--Traps, wire leads and funnel.

into the trap (Fig. 3). The leads were held in place by two 2-3 ft. rods woven through the end of the chicken wire leads and sides of the entrance to form a "V" into the trap.

The trap was secured at ground level with 2-3 metal stakes pounded into the ground. Metal or plastic tent stakes worked to secure the traps, but are expensive. The top of the trap was covered with soft fish netting which overlapped

the sides. The netting was held in place with open hog rings used as hooks to hold the netting down along the sides of the trap. The mesh of the netting should be small enough so the bird cannot get their wings or head through it. The tops should not be covered with wire as the birds will scrape their heads and wings when trying to escape.

A funnel at the entrance into the trap is essential to prevent trapped birds from finding their way out (Fig. 3). Funnels were made of chicken wire and extended approximately 8 inches into the trap. The opening into the funnel should be 6-8 inches high and drop down to 4 inches.

Hens were captured in both baited and unbaited traps. Some hens were attacted to the bait while others showed no interest. The use of bait can create problems as it will attract cocks to the traps.

Traps set on the booming ground for the first time will capture some cocks. The number of cocks captured can be reduced by leaving the traps closed for at least a day while the cocks learn to avoid the closed entrances. However, some cocks will still be captured usually when they move onto the grounds in the early morning. Cocks should be removed from the traps as soon as possible because their behavior will discourage hens from entering a trap. Hens will go into traps with other hens, but will hesitate to enter a trap with a cock present. We have left cocks and hens in traps up to 45 minutes with no problems. However, if 2 cocks or a hen and a cock became caught in the same trap they should be removed immediately to avoid injury.

To avoid injury and prevent birds from being captured inadvertently the traps should not be left unattended or opened before the cocks go to roost at night. It is best to open the traps in the morning before the cocks begin to display or at least 1 hour after the cocks have gone to roost.

Walk-in traps have been set on the same booming ground from 1 April-10 May. Cocks appeared to adjust to the wire leads and traps usually within a day. For morning trapping it was best to set the trap the day before and let the cocks adjust to the traps and leads during the evening display period. Some cocks that were captured several times were known to shift their territories away from traps and leads. All cocks were banded and none were known to abandon the booming ground.

During the 1983 and 1984 breeding seasons we trapped 46 prairie grouse hens in 60 days using the "W" walk-in traps on 4 booming grounds in North Dakota. The earliest a hen was captured was on 2 April and the latest on 3 May. Most hens (70%) were captured from 17-25 April. In addition to walk-in traps 3 hens were captured with rocket nets and 4 with bownets in 1983.

A comparison of the 3 trapping methods showed that the walk-in traps were approximately 3 times more efficient (0.29 hens/hour) than the rocket nets (0.10 hens/hour) and 6 times more efficient that bownets baited with corn (0.05 hens/hour). The walk-in trap also captured a higher percentage of the hens present on the booming ground than rocket nets (16.7% vs 4.7%). In an earlier study in Minnesota in 1977, it took 4 men, 122 hours to capture 20 hens on booming grounds using rocket nets (0.16 hens/hour and 14.2% of the hens) (Toepfer unpubl. data).

Only 1 of 65 birds captured in walk-in traps died. This mortality was due to 2 cocks getting in the same trap and being harassed by a redtail hawk (<u>Buteo jamaicensis</u>) before the observer could get to the trap. One of these 2 birds suffered a broken wing in the encounter and was collected. By contrast the mortality rate for rocket nets was 3%.

The traps without leads were also used to capture individual prairie chicken cocks by placing a trap baited with corn in a cock's territory. The "W" system with traps baited with corn was also used to trap cocks and hens in winter feeding areas. However, because of the behavior of birds once inside the traps usually only 1, or at most 2 birds were captured at a time. The traps with leads should be effective on the display ground during fall and in intercepting and capturing a few birds in fall feeding areas when food is not limited. Ligon (1946) also felt that wire leads could be used to intercept and trap prairie chickens as they moved to and from feeding areas.

The "W" system has also been used to capture lesser prairie chickens (<u>Tympanuchus pallidicinctus</u>)and sage grouse (<u>Centrocercus urophasianus</u>) hens. No cost figures are available, but several walk-in traps can be purchased for the price of a single rocket net setup.

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Summer Brood-Rearing Ecology of the Greater Prairie Chicken on the Sheyenne National Grasslands[1,2]

Jay A. Newell,[3,4] John E. Toepfer,[3] and Mark A. Rumble[5]

Abstract--Twenty-two radio-tagged hens hatched 265 chicks, of which all but 4 left the nest. Mortality of chicks was high, especially in the first 24 days, with only 28.4% surviving to the end of summer. Brood ranges varied from 22 to 2248 ha with an average of 488.6 ha for 15 broods that had at least one chick alive on 10 August. Several factors influenced the size of the range, including timing of the nest, age of the hen, and loss or potential loss of young due to predation, mowing or grazing. Small areas within the total range were used more intensively. These areas averaged 40.4 ha. Broods were relocated in native vegetation 70.1% of the time. When in native vegetation they were found in lowlands, midlands and uplands 45.5, 26.9 and 23.2% of the time, respectively. Broods seldom night roosted in upland vegetation, the community most heavily grazed by cattle. Broods were seldom relocated in pastures with cattle (26.8%) and usually left areas once they were mowed. Deferred pastures contained the greatest number of intensive use areas, 10, while prairie hay and alfalfa had 8 and 5 respectively. Population declines in recent years might be due in part to the poor brood survival.

INTRODUCTION

Quantity of grassland vegetation appears to be directly related to pairie chicken (Tympanachus cupido) population levels (Schwartz 1945, Baker 1953, Hamerstrom et al. 1957). However, quality of the grassland vegetation is also important (Christisen and Krohn (1980).

Lack of quality grassland most often affects the availability of nesting and brood-rearing habitat, considered to be the most important factor influencing prairie chicken population levels (Hamerstrom et al. 1957, Kirsch 1974, Westemeir 1980). Although spring and summer ecology of hens and broods is important, it is probably the least understood period in the life cycle of the prairie chicken (Hamerstrom and Hamerstrom 1973). Radio telemetry studies have povided some information on habitat use and movements during the brood rearing period (Silvy 1968, Bowman and Robel 1977, Svedarsky 1979) but more information is needed.

This study was initiated in the spring of 1983 to:

(1) determine the brood-rearing habitat requirements of the greater prairie chicken,

(2) evaluate grazing management practices and their effects on prairie chicken habitat, and

(3) develop compatible management recommendations for prairie chickens and livestock.

Field work was conducted from March through August in 1983 and 1984 on the north unit of the Sheyenne National Grasslands, North Dakota.

This study was funded by the USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Rapid City, SD. The assistance of Robert Riddle, William Fortune, and Mike McNeal of the Sheyenne National Grasslands District, Custer National Forest, and the members of the Sheyenne Valley Grazing Association is gratefully acknowledged. R. L. Eng is acknowledged for his constant support, shared experience, and guidance throughout the project.

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[2] Contribution No. 2142, Montana State University Agriculture Experiment Station.

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STUDY AREA

The north unit of the Sheyenne National Grasslands District of the Custer National Forest (SNG) is located approximately 36 km southwest of Fargo, North Dakota. It encompasses approximately 27,150 ha of USFS land interspersed with 25,338 ha of private land. The primary economic use of the SNG was cattle grazing. The private land was used for pasture, alfalfa hay (Medicago spp.), prairie hay, or cash crops.

Grazing on public lands usually began 15-20 May and ended 15-20 November. Management of pastures varied on a yearly basis and between allotments depending upon pasture size, stocking rates, and weather conditions. The most common grazing systems were the 3-pasture deferred, 2-pasture rotation and continuous system. Lessees were encouraged to mow "rank" vegetation in lowlands of the deferred pastures and first pasture grazed of the 2-pasture systems between 15 July and 15 August. Lessees were occasionally allowed to mow lowland vegetation in the continuous systems and in other pastures besides those previously mentioned.

METHODS

Forty-six prairie chicken hens were captured using paired rocket nets, bownets (Anderson and Hamerstrom 1967), and walk-in traps. Captured birds were aged by outer primary wear (Petrides 1942, Wright and Hiatt 1943, Ammann 1944). Hens entering their first breeding season were considered juveniles throughout the summer while all others were adults. Radio transmitters mounted on a bib (Amstrup 1980) were placed on captured birds then they were released on or near the display ground of capture. Two types of solar-powered radio transmitters were used with mean weights of 16.8 and 22.0 grams.

Most relocations were made using a single eight-element 3.8 m antenna mounted on a vehicle. Bird locations were determined by triangulating from two or three recognizable points on 1:660 air photos. Ground to ground range was between 0.8 and 1.6 km. Estimated accuracy using similar equipment was 41 m at distances from 305 to 537 m (Toepfer 1976). A fixed-wing airplane with a two-element yagi mounted on each strut was used occasionally to relocate birds. Hand held yagis were used to pinpoint hens on nests and to periodically flush hens. An attempt was made to locate broods at least once every other day through August.

Night roosts of hens were periodically marked by approaching hens in the dark and flagging nearby vegetation. The roost was found the next day by searching the area with a dog. Height-density of vegetation at the center of the roost was estimated using a Robel pole (Robel et. al. 1970).

Radio locations were digitized into an X-Y coordinate system using the Universal Transverse Mercator Grid (UTM) (Avery and Berlin 1977) and were entered into a computer program TELDAY (Lonner and Burkhalter 1983) to determine home range area. Home range was defined as the area enclosed by connecting the outer perimeter of points (Hayne 1949). Only ranges of hens with at least one chick alive on 10 August were used to calculate mean brood ranges. Within the total brood range, hens spent a greater portion of time in small areas called intensive use areas (IUAs). IUAs were areas where all relocations for at least five consecutive days fell within a small area relative to the total brood range. The assumption was made that hens remained within the IUA between successive locations. Distances were measured between IUAs as an indicator of brood mobility.

The vegetation surrounding booming grounds on which birds were captured was cover-typed in early May and late August of each year. Vegetation was classified into the following height classes: Class I (0-8 cm); Class II (9-25 cm); Class III (26-50 cm); Class IV (over 51 cm). Each location of a prairie chicken was assigned to one of the above height classes and a community type. Community types included upland, midland, lowland (Manske 1980), grass/shrub, lowland II (dominated by prairie cordgrass (Spartina pectinata)), alfalfa, or planted prairie hay. Community types were: determined from SCS air photos superimposed over radio relocations; or recorded at night roosts, nest sites, or sites where birds were flushed.

Each relocation was assigned a land disturbance type based on past and present land use, pasture type, cattle presence, private land use, and ownership. Analyses of use of disturbance types by prairie chickens were based on whether the areas selected were grazed or mowed and whether the disturbance type selected after hatching was more disturbed, less disturbed, or as disturbed as the type the nest was in. Even though an IUA may have consisted of more than one disturbance type, it was assigned assigned the disturbance type from which the most relocations were recorded. The total number of days broods spent in each disturbance types was then calculated.

In cases where a relocation was within 41 m of another community or disturbance type, those relocations were originally assigned a code for edge. However, there were relatively few edge relocations for disturbance type so edge codes were not incorporated in disturbance type analysis.

Vegetation in four communities -- upland, midland, lowland, and planted prairie hay -- was monitored for changes in height and density along 21 photo-plot transects throughout the summer (Newell 1987).

To compare early and late brood mortality, the summer was divided into two time periods,

from hatching until the first time the brood was flushed and from the first flush until the end of the summer. If a hen was killed during the brood period it was assummed that the chicks also died.

RESULTS

Movements and Home Range

Brood hens utilized IUAs for periods ranging from 7 to 57 days (mean=24.8 days SD=14.9). Twenty hens had 40 IUAs identified during the course of this study. Four hens who lost their broods or were killed early in brood-rearing were not included in calculations of mean IUAs (Table 1).

Table 1. Average size of intensive use areas of broods on the SNG, 1

Age	Mean (ha)	SD	No. area
Adult	40.5	47.7	19
Juvenile	40.2	50.3	17
Total	40.4	48.2	36
After Renest	21.6	11.7	11
After Initial	48.6	55.7	25

Mean distance from the nest to the first IUA was 0.47 km (SD=0.56) with little difference exhibited between adults and juveniles (Table 2). Mean distances to the second and third IUAs were over two times greater for juveniles than adults. The furthest distance moved by an adult with a brood between IUAs was 2.3 km, while 3 of 10 juveniles moved from 2.4 to 10.5 km with broods 12 to 34 days old.

Mean brood range sizes were largest for juvenile hens that hatched initial nests (Table 3). The smallest brood range for any juvenile that hatched an initial nest and had chicks at the end of the summer was 229 ha which was larger than all adult brood ranges except one. Individual brood rearing ranges varied greatly from 22 - 2248 ha, and averaged 488.6 ha (SD=709.5, n=15).

Table 3. Mean brood range size of adult and juvenile prairie chicken hens.

Age	Nest Type[1]	x-(ha)	SD	N
Adult	I	255.8	99.8	4
Juvenile	I	1178.8	915.5	5
Combined	I	768.6	812.1	9
Adult	R	77.5	42.3	4
Juvenile	R	51.0	35.4	2
Combined	R	68.7	38.9	6
Adult	R&I	166.6	118.8	8
Juvenile	R&I	856.6	928.4	7
All Combined	R&I	488.6	709.5	15

[1] I = Initial nest, R= Renest.

Habitat Utilization

Community type locations were recorded for 921 hen relocations during the brood rearing period. Most of the use associated with agricultural communities was in alfalfa and planted prairie hay. Of all brood locations in agricultural communities, 87.3% were in planted prairie hay (37.9%), alfalfa (41.0%), or in associated edge communities (8.4%). Hens decreased use of agricultural community types by 23% in August. Three broods used alfalfa almost exclusively. Following the mowing of alfalfa, brood hens remained near the fields but used the edge of windbreaks, ditches, and adjacent prairie hay for cover. Twenty-nine (12.7%) of all brood locations in non-native communities were recorded in cash crops or their associated edge, most of which were those of one brood.

Brood hens were relocated in native vegetation (public and private land) 70.1% of the time. Structurally, the vegetation in midlands and lowlands was similar, and differentfrom uplands. Upland vegetation was heavily grazed by cattle throughout the summer. Most brood relocations were in the lowlands with the highest use occurring in June when lowland vegetation was much taller and denser than upland or midland vegetation (Table 4).

Table 2. Mean distance (km) moved by brood hens from nest site to first intensive use area, and mean distances between subsequent intensive use areas.

Age	km from nest			km to second			km to third			km to fourth		
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Adult	0.57	0.66	9	1.01	0.36	6	1.03	0.28	4	1.12	-	1
Juvenile	0.39	0.47	11	2.83	3.94	6	2.86	1.19	3	-	-	0
Total	0.47	0.56	20	1.92	2.83	12	1.82	1.21	7	1.12	-	1

Table 4. Percent use of native communities, combined with their respective edges, by broods.

Community type	June %	June N	July %	July N	August %	August N
Upland	22.5	41	26.0	66	20.5	43
Midland	25.8	47	25.5	65	29.5	62
Lowland	48.3	88	44.1	112	44.8	94
Grass/shrub	3.3	6	4.3	11	5.2	11

Mean Robel pole reading from 43 night roosts of brood hens averaged 1.04 (SD=.68). Thirty-seven (86.0%) were located in Class III or taller vegetation while none were recorded in Class I vegetation; only 18.6% of all brood night roosts were found in the upland community.

Fifty-six percent of all brood locations were on public land (Table 5). Although in July broods spent more time on private land . Brood hens often used areas that had been mowed the previous year, with 30.4% and 45.9% of the relocations in prairie hay or alfalfa, respectively, in June and July. Alfalfa and prairie hay use by broods declined to 24.8 % in August due to the mowing of those community types. Hens with out broods left mowed prairie hay fields, whereas those with broods sometimes remained in or near mowed alfalfa fields.

In June, July, and August 64.9, 49.5 and 60.8% of all brood locations, respectively, were in pastures. Three-pasture deferred systems were used most by broods in all months (Table 5). Within 3-pasture systems, 53.9% of the locations were in the deferred pasture. Pastures deferred one and two years prior had 30.7 and 15.4% of the locations, respectively. Hens tended to avoid pastures with cattle and pastures that had been grazed earlier that year. Seventy-three percent of all brood locations were in disturbance types without cattle.

After hatching, hens often moved their broods from the disturbance type in which they nested, to a different disturbance type. Of 19 hens that made a selection of disturbance type following hatching, 6 moved their broods from areas with cattle to areas without cattle and 9 stayed in disturbance types that were undisturbed (unmowed or ungrazed) in the current year. Of the 4 that remained in grazed pastures, one lost her brood within 6 days, two stayed in the more disturbed area for 7 and 11 days, and one remained in a relatively undisturbed portion of a grazed pasture throughout brood rearing.

Forty-three percent of all locations of hens with broods were in deferred pastures and prairie hay. Analysis of IUAs suggested that hens selected those areas because of the lack of disturbance. Eighteen of 40 IUAs consisted mainly of prairie hay or deferred pastures, while 47.7% of all brood days were spent in those types (Table 6). Two other disturbance types

Table 6. Disturbance types that were the major components of intensive use areas (IUAs) and the number of brood days spent in each.

Disturbance type	No. IUAs	No. Days	N[1]
4-pasture	2	25	2
3-pasture[2]	1	10	1
3-pasture[3]	6	154	4
3-pasture[4]	10	243	7
2-pasture[2]	3	59	7
2-pasture[3]	1	10	1
1-pasture	2	38	2
Prairie hay	8	197	7
Alfalfa	5	143	4
Barley	1	23	1
Private pasture	1	20	1
Total	40	922	32

[1] Number of different broods.
[2] First pasture grazed.
[3] Second pasture grazed
[4] Deferred pasture.

Table 5. Number and percent of relocations in disturbance types for brood hens June-August, 1983-1984.

Disturbance type	June No.	June %	July No.	July %	August No.	August %	Total No.	Total %
Public[1]								
4-pasture	11	4.1	5	1.3	3	1.1	19	2.1
3-pasture	95	35.2	130	33.9	119	44.1	344	37.3
2-pasture	11	4.1	30	7.8	7	2.6	48	5.2
1-pasture	58	21.5	25	6.5	35	13.0	118	12.8
Private								
Prairie hay	11	15.2	131	34.2	43	15.9	215	23.3
Alfalfa	41	15.2	45	11.7	24	8.9	110	11.9
Crops	3	1.1	10	2.6	13	4.8	26	2.8
Misc.[2]	10	3.7	7	1.8	26	9.6	43	4.7
Total	270	100.0	383	99.8	270	100.0	923	100.0

[1] Includes nine locations in grazed pastures, private land
[2] Includes road ditches and undisturbed areas.

Table 7. Range of heights (HT) and densities (EHT) (cm) of vegetation along photo-plot transects.

Vegetation	Upland			Midland			Lowland		
	June	July	Aug.	June	July	Aug.	June	July	Aug.
EHT[1]	3-6	7-12	8-12	8-12	17-20	20-21	8-18	25-30	6-1
HT[1]	11-21	22-31	31-33	22-30	35-40	40-48	20-36	22-50	17-22
EHT[2]	3-4	3-6	3-5	8-10	10-11	9-11	7-10	9-14	11-14
HT[2]	12-13	9-11	7-11	27-28	22-27	24-25	16-23	20-31	25-31
EHT[3]	5-6	9-11	5-11	7-10	12-14	12-14	10-14	18-22	18-22
HT[3]	15-17	20-28	16-28	19-25	24-28	24-29	25-33	46-59	46-59
EHT[4]				3-13	17-21	2			
HT[4]				9-23	34-42	6			
EHT[5]							16-29	35-39	35-39
HT[5]							31-51	61-72	69-72

1 3-pasture, deferred pasture.
2 3-pasture, deferred 1 year prior.
3 3-pasture, deferred 2 years prior.
4 prairie hay.
5 continuous system. Lowland II community.

contained significant numbers of IUAs, the second pasture grazed of 3-pasture systems and alfalfa. In all but one case, hens utilized the second pasture grazed when cattle were not present, and the undisturbed edges of alfalfa fields when they were mowed.

Prairie hay and deferred pastures represented a small portion of the area available to a hen. Height and density of vegetation was superior in all communities in the deferred pasture (ungrazed) in June and July (Table 7). Height and density of vegetation was similar to the deferred pasture in the undisturbed prairie hay in July. Lowland and prairie hay vegetation was mowed in August which accounts for the tremendous reduction in height and density in that month. Lowland vegetation that received the most use was the tallest and densest in most disturbance types during the summer. Even though hens nested in and broods were relocated close to the lowland II community, they were seldom observed in it. The lowland II community may have contained vegetation too tall and dense for easy brood movement.

Brood hens selected Class III (26-50 cm) or taller vegetation 81.8% of the time throughout the summer. Hens appeared to avoid Class II or shorter vegetation, especially as the growing season progressed and taller vegetation became more available (Table 8).

Table 8. Height class of vegetation used by brood hens on the Sheyenne National Grasslands, 1983-84.

Height Class (cm)	June No.	June %	July No.	July %	August No.	August %
I (0-8)	15	5.7	6	1.6	5	1.9
II (9-25)	23	8.7	12	3.2	24	9.0
III (26-50)	150	56.8	202	53.2	116	43.4
IV (> 51)	38	14.4	135	35.5	94	35.2
edge[1]	38	14.4	55	24.7	28	10.5

1 Locations within 41m of two height classes.

Brood Mortality

Twenty-two radio-tagged prairie chickens produced 265 chicks, all but 4 of which left the nests. Mortality of broods was high, especially during the first 2.5 weeks of brood rearing. Three hens made 3, 11, and 9 km moves 1, 5, and 10 days, respectively, after hatching. Periodic marking of roosts, and flushing, indicated they had each lost their entire brood prior to these moves. In addition, five hens were killed during the brood rearing period, three within 17 days after hatching and two after 45 and 53 days.

Brood hens were first flushed an average of 24 (SD 13.1) days after leaving the nest. Mortality during this early period averaged 0.31 chick per day per hen, resulting in a loss of 62.8% of the chicks. The average number of days to the end of the summer was 32.9 (SD 12.48) days. Mortality during this later period was 0.04 chick per day per hen, resulting in a loss of 8.9% of the chicks.

Of 261 chicks that left the nest, only 28.4% (74) survived to the end of the summer. Average brood size for 13 hens that had chicks at the end of the summer was 5.7 (SD = 3.75). In two years, 45 prairie chicken hens had only 74 chicks survive until 31 August. Of the 22 radio-tagged prairie chicken hens that produced chicks, only 13 had one or more chicks at the end of the summer.

DISCUSSION

Brood Movements and Home Range

Earlier studies indicated that hens with broods remained in the area of the nest following hatching (Schwartz 1945, Hamerstrom and Hamerstrom 1949). With the advent of radio telemetry, investigators found that broods were capable of making extensive moves within the first week of hatching (Viers 1967, Silvy 1968, Svedarsky 1979). Our data agree, and show that hens with broods were very mobile with five hens moving 2.0 to 10.5 km within 34 days of hatching.

Brood ranges in this study showed great varability, from 22 - 2248 ha, but are greater than previously reported in other areas. The smallest range for a hen which hatched an initial nest and had chicks at the end of the summer was 197 ha.

Several factors appeared to influence the size of the brood home range. All broods hatching from renests had smaller ranges than broods from initial nests. Successful renesting hens generally had much more restricted movements compared to hens having successful initial nests. Vegetation development, food availibility, and greater energy outlay for renesting hens might have influenced hen movements following hatching. Others have found that prairie chickens tend to become less mobile as summer progresses (Svedarsky 1979, Robel et. al. 1970).

Age of the hen seemed to influence brood range size. Females in their first breeding season had much larger ranges than adults. The largest move made between intensive use areas by any adult was 2.3 km, while four of six juveniles hatching initial nests made at least one move over 2 km.

Early long moves and subsequent larger home ranges of brood hens may have resulted from hens searching for suitable brood-rearing habitat (Svedarsky 1979). Suitable brood habitats have been described as areas that had been mowed, burned, or grazed the previous summer, and without tall, rank vegetation (Svedarsky 1979, Skinner 1977, Toepfer 1973,). Most of the SNG and associated land is disturbed annually by mowing, grazing, or cultivation with relatively small tracts of land going undisturbed for a period of time in any given year. Hens in this study appeared to avoid areas disturbed in the current year and utilize areas that were undisturbed or had minimal disturbance in the current year. The large brood ranges in this study might have been partially in response to disturbances such as mowing and grazing and/or brood predation.

Five hens remained in undisturbed IUAs that ranged in size from 9 to 83 ha. Two of the IUAs were in prairie hay and one each in alfalfa, the deferred pasture of a 3-pasture system and the first pasture grazed of a 2-pasture system. The average number of days spent in those IUAs was 31 (SD=19.7) and ranged from 11 to 57 days. Within three days of mowing, hens moved an average of 1.2 km, which may have resulted in increased mortality to chicks. One hen with 12-day-old chicks moved 1.5 km after the alfalfa she was in was mowed. Another hen which remained near a mowed alfalfa field was killed by a predator shortly after the second cutting.

Cattle appeared have to caused at least one hen to move from the area. Hen 1270 had spent 32 days in a 35-ha IUA in the deferred pasture of a 3-pasture system. Three days after cattle were introduced she moved from the pasture. Although only one hen was observed to shift immediately upon cattle entry into the pasture, only 27% of all brood relocations were in pastures with cattle, and hens appeared to avoid establishing IUAs in areas with cattle.

Attempted brood predation appeared to prompt moves. Sharp-tailed grouse (T. phasianellus) broods made long moves after the female was captured, and those moves may have been precipitated by the capture (Artmann 1970). Svedarsky (1979) hypothesized that it may be advantageous for a hen to move out of an area following a predator encounter, and that researcher approaches may be viewed as predator encounters. Some support for this hypothesis was noted in this study. A hen and brood moved 4.2 km following a flushing during which one of her chicks was accidently killed. This was the only instance where a brood hen moved immediately after being flushed. Five other shifts may have been caused by predator avoidance. A hen with a brood of 8 was oftened observed in close proximity to a perching Swainsons hawk (Buteo swainsoni). The hawk was observed on the ground near the hen and brood on 8 July. Subsequently, the hawk was flushed but no dead chicks were observed. However, the following day the hen moved her brood 10.5 km from the site. Another hen moved from her nest into a pasture with a fox den with six pups. After spending seven days in this pasture, the hen abruptly moved 1.5 km west of the area. Although 13 eggs had hatched only 2 chicks remained following the move. Moves of 3.2, 11.1 and 9.7 km were noted for hens that lost entire broods.

In summary, it appeared that the size of individual brood ranges was influenced by the timing of nest, age of the hen and loss or potential loss of chicks due to predation or habitat alteration.

Habitat Use

It appeared that disturbance types with suitable cover were selected for brood IUAs. Brood IUAs averaged 40.4 ha and might be considered a suitable management unit. Vegetation in lowlands and midlands of deferred pastures and prairie hay had superior height and density compared to grazed pastures. After mowing in late July or early August this was no longer true. Night roosts were in vegetation

that provided complete visual obstruction over 1 dm with heights over 2.5 dm. Broods used lowlands and midlands more than uplands both day and night because of the superior cover provided, avoiding areas of sparse vegetation (Horak 1985). Rice and Carter (1984) reported that brooding hens selected the best available habitat with ample vegetation. Hens with broods in this study utilized vegetation which provided visual screening in excess of 2.5 dm in all summer months. Hens also avoided areas with sparse vegetation resulting from heavy grazing of uplands and mowing of prairie hay fields and lowlands. Hens appeared to avoid pastures with cattle present or areas with very tall and dense vegetation.

Although data were not collected on species composition at brood rearing sites, hens may have selected IUAs with concentrations of high-energy forbs such as alfalfa or sweet clover (Melilotus spp.). Five IUAs were located in alfalfa and 8 in prairie hay that was adjacent to or contained alfalfa. Diet analysis from fecal samples (Rumble et al., this proceedings) showed a high composition of alfalfa/sweet clover in the diets of brood hens. Svedarsky (1979) found that broods showed a preference for alfalfa fields.

Brood hens avoided cash crops, especially row crops during the summer and selected lowlands over midlands and midlands over uplands. Three percent of all brood relocations were in cash crops. Arthaud (1968) and Svedarsky (1979) also reported that prairie chickens spent little time in cultivated crops. Thus, with the exception of use made of mowed alfalfa, brood hens chose the areas on the SNG with relatively undisturbed vegetation.

Mortality

Mortality of chicks in this study was very high, with only 28.4% of the chicks surviving to the end of the summer. Chick mortality during the first 24 days appeared to be much higher than later periods. Mortality of hens was also high; 21 of 44 hens died during the spring and summer months (April - August). Most of the adult mortality was the result of predation, but the causes of chick mortality could not be determined. Populations of prairie chickens on the SNG have declined from 391 males in 1983 to 202 males in 1986, and these declines may be in part due to poor brood survival. There is a need to provide more areas 40 ha or greater with undisturbed vegetation that provides visual screening to 2.5 dm in height during the brood-rearing months on the SNG.

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Winter Ecology of the Greater Prairie Chicken on the Sheyenne National Grasslands, North Dakota[1,2]

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Abstract.--Twenty radio-tagged prairie-chickens (6 cocks, 14 hens) were followed during the winter of 1984-85 on the Sheyenne National Grasslands in North Dakota. A total of 3,945 (2,879 day and 1,066 night) locations were obtained from 9 December to 15 March. Winter survival was high at 58.8%. Mean winter home range size was 8.4 km^2 and slightly larger for hens than cocks (8.8 km^2 vs 7.7 km^2). Mean winter to spring movements were 4.4 km for cocks and 6.4 km for hens. All locations were within 6700 m of a known booming ground; 64% were within 2400 m with a mean of 2078 ± 980 m. Cocks remained closer to booming grounds than hens (Mean = 1797 ± 709 vs 2327 ± 1178 m). Mean movements from day areas to night roosts were 1085 ± 778 and were greater for cocks than hens (1358 vs 1035 m). Mean within day movements were less at 992 m for cocks and 899 for hens. When possible, radioed birds did not use the same roosting area on successive nights as the mean distance between successive night locations was 922 m. Agriculture and grass made up 71.3% of all the winter habitat types used by radioed birds (Agriculture 41.7%, Grass 29.6%). Picked corn made up 70.8% of the agricultural use. Habitat used at night was dramatically different from that used during the day; 66.7% of the night locations were in grassland habitat and 11.8% in shrubs, primarily snowberry. Lowland grass and sedges accounted for 64% of the night use. A breakdown by vegetation height classes showed that 78% of all locations were associated with 9 cm or taller vegetation; 59% with 25-50 cm cover. Over 75% of the night use was in 25 cm or greater vegetation and 77.9% in cover undisturbed within the past 8 months. Within these undisturbed areas night roosting prairie-chickens selected the taller available cover.

INTRODUCTION

Since the 1960's, winter ecology of the greater prairie chicken (Tympanuchus cupido pinnatus) has been largely ignored. Past studies that dealt with winter were limited with regard to movements and habitat use (Schmidt 1936, Grange 1948, Hamerstrom and Hamerstrom 1949, Baker 1953, Ammann 1957, Hamerstrom et al. 1957, Robel et al. 1970a and Horak 1985).

This study was initiated to examine the winter ecology of the greater prairie chicken on the Sheyenne National Grasslands (SNG) and to explore the effects of grazing practices on winter habitat of this bird. Radioed hens were monitored from mid-December 1984 until incubation which provided movement patterns from winter to spring.

We gratefully acknowledge the following: Robert Riddle, William Fortune and Mike McNeal of the U.S. Forest Service, Lisbon, North Dakota for their cooperation and logistical support; the North Dakota Game and Fish Department for generously providing a vehicle throughout the winter; and finally Joe Milton, members of the Sheyenne Valley Grazing Association and residents of the area, whose acceptance of and cooperation with the field activities, not only contributed considerably toward the completion of this study but made working in the area much more enjoyable.

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STUDY AREA

The Sheyenne National Grasslands (SNG) is located 36 kilometers (km) south of Fargo, North Dakota. The north unit of the SNG contains 52,488 ha of which 48.4% is private and 51.6% is public land managed by the U.S. Forest Service in association with the Sheyenne Valley Grazing Association.

The terrain varied from level to rolling hills referred to locally as sandhills. The area is relatively open, but dotted with scattered solitary trees and small clumps of cottonwood (Populus deltoidies), aspen (Populus spp.) and Oak (Quercus spp). The grassland areas vary from level to rolling with grass-covered sand dunes 1.5-3 meters (m) above the level lowlands, which vermiculate between and through the higher uplands.

Manske (1980) divided the grasslands into 3 major communities: Upland (mixed grass prairie dominated by blue gramma (Bouteloua gracillis) and Kentucky bluegrass (Poa pratensis); Midland (tall grass prairie) dominated by big bluestem (Andropogon gerardii), little bluestem (Schizachyrium scoparium), Kentucky bluegrass and switchgrass (Panicum virgatum); Lowland (sedge meadow) dominated by sedge (Carex spp. and Carex lanuginosa), blue grass, reed grass (Calamogrostis spp.) and switch grasses (Panicum spp.).

The SNG was managed using a multiple pasture system (1,2,3 or 4 pastures), primarily 3 pasture units. All 2,3 or 4 pastures were grazed at least once during the period May - November. One of the 3 or 4 pastures was usually deferred during the peak of the growing season. Most level lowlands were mowed once every 3 years to stimulate growth and encourage cattle to graze the lowlands.

METHODS

Trapping

Prairie chickens were captured in traps constructed of lengths of welded wire (approximately 0.7 X 3 m) with 2.5 cm mesh. The wire was staked to the ground in a circle forming a funnel on one side and covered with fish netting. Three to 5 traps were placed in known feeding areas and baited with cobbed corn. Age, adult or immature, was determined by primary feather molt and wear (Petrides 1942, Wright and Hiatt 1943, and Ammann 1944) and by depth of the bursa (Gower 1939, and Kirkpatrick 1944).

Movements

Radio transmitters (SM1 Type, 12-16 g. and SB2, 19-22 g AVM Instrument Company, Dublin, California) were in the 150-151MHz frequency range. Transmitters were powered by solar panels connected to a NiCad battery that stored power. The units were attached to the bird using a bib system similar to that used by Amstrup (1980). The larger units had a reduced antenna (16 cm) to prevent them from slapping the bird's wings inflight. The smaller units had full length antennas (25 cm) held forward at a 45 degree angle by a spring to avoid wing slapping. Two birds were radioed with back pack units (Dumke and Pils, 1973).

Radioed birds were located by triangulation with an AVM, LA12 receiver connected to a single 3.4 m high, 8 - element yagi antenna mounted on a vehicle. Ground to ground range of the system was respectively. Average accuracy using signal nulls for known transmitter locations (night roosting birds) with angles of intersection of between 60 and 120 degrees was $27.8 \pm 15.4_m$ (n = 78) from 262-1016 m (Mean = 479.8 ± 189.2). At night, birds were located by approaching with a vehicle to within 5-20 m, marking the line and locating the roosts the next day for detailed analysis.

Each location was recorded as to date, time (CST), straight line distance to the last location, distance to the nearest booming ground, home or regular booming ground, nearest sharptail dancing ground, type of movement, habitat, disturbance type, vegetation height class and activity. The distances between locations were stratified into 2 types of daily movements: (1) the distances between a daytime and a subsequent night location (daylight to night move) and (2) distance between consecutive night locations. The distance to the nest was measured to the first known nest. The home booming ground for cocks was the one on which they displayed and for hens the one nearest their first nest. Home range is that defined by Burt (1943) and its area calculated by enclosing the outer perimeter (Hayne 1949).

Habitat Use

Habitat types were classified using cover type maps of the areas drawn from aerial photographs. Ocular percentage estimates were used to place cover into 7 general categories: Grass, Forbs, Agricultural, Shrubs, Wetland, Trees, and Other. Paired combinations of these categories i.e. Grass 80-100% equaled Grass, whereas a mixture of 50-75% Grass and 25-50% Forbs equaled Grass/Forbs. A shift in composition favoring Forbs (greater than 50%) was classified as Forbs/Grass habitat. These general categories were then visually classified according to the dominant plant specie(s). Disturbances were classified as to the type of disturbance within the last 8 months (undisturbed, agricultural, grazed, mowed). Vegetation height classes were established relative to the height of a standing prairie chicken. Class I up to the belly of a bird (0-8 cm), Class II up to the eye of a bird (9-25 cm), Class III above the birds head (26-50 cm), Class IV (51-100 cm) Class V (1-2 m) and Class VI (over 2 m). In addition to the major categories, habitat, disturbances and height were classified as an edge type when a location was

within 55 m of a different habitat or disturbance. This compensated for the limitations in the accuracy of the radio locations and reduced the possibility of placing the location in the wrong habitat type.

Night Roost Analysis

The following data were collected at each roost: Robel pole (Robel et al. 1970b), snow depth, last disturbance, height class, distance nearest roost, maximum distance between roosts, depth of roost in snow, distance to nearest edge, type and disturbance of edge, and distance to feeding area. Random measurements were taken at points one meter apart along a line parallel to where the birds roosted.

Other

Maximum and minimum temperatures and depth of snow were recorded daily. Official precipitation records were obtained from the U. S. Weather station 2 miles east of McLeod. Winter was that period when 7 cm of snow had accumulated covering most ground level foods (15 December - 17 February) and early spring the period after the snow was gone (18 February - 15 March). In addition to the winter period, data were stratified into weekly periods.

The day was divided into two periods, daylight and dark. Daylight hours were stratified into 3 equal periods (AM, MIDDAY, PM) begining 1 hour before sunrise and ending 1 hour after sunset.

We emphasize that statistical or mathematical differences may or may not be biologically significant and that they are largely guides to possible differences. Our personal observations of prairie grouse suggest that they exist within ranges limited by their biological and physiological capabilities, individual experiences, and conditions at a given point in time. Therefore we have chosen to primarily identify common trends and patterns from which management decisions can be made. Means and ranges are presented in parentheses and the $\pm$ symbol represents 1 standard deviation.

RESULTS AND DISCUSSION

Weather

The winter of 1984-85 on the SNG can best be described as having average temperatures, below normal snowfall and an early spring. Mean temperature for winter was 3.9F (SD $\pm$ 12.3) and ranged from 29-33. At times the wind chill factor reached 40 to 50 below, 80 below on 19 January. Snow remained on the ground 64 days from 15 December to 17 February. Snowfall during the study period was 18 cm (7 in) during winter and 22.9 cm (9 in) in early spring. Average annual snowfall is 91.4 cm (36 inches) and average snow on the ground during winter ranges from 13-18 cm (5-7 in) for 80 days (DTP Background Report, 1979).

The regular presence of strong winds (1-60 mph) caused snow to drift. Some habitat types (lowlands, brush, windrows and fencelines) accumulated drifted snow, while ridges and parts of agricultural fields were often blown free of snow.

Radio-tagging

Eight cock and 15 hen prairie chickens were radio-tagged, 14 of which (4 cocks and 10 hens) received the larger, more powerful SB2 transmitters. In addition 3 hens radio-tagged the spring of 1984 were followed through the winter 1984-85.

Radio Locations

Twenty radioed prairie chickens (14 hens and 6 cocks) yielded 2879 day and 1066 night locations. The distribution of the radio locations were evenly distributed throughout the day (AM, Midday, PM, Night) (ChiSq. P = 0.47, df 3).

Flocking

On the SNG in winter and early spring 89% of 335 prairie chicken observations were of groups of 2 or more. Mean flock sizes for radioed and non-radioed prairie chickens were comparable (Mean = 7.9 $\pm$ 9.3, n = 154 vs Mean = 6.1 $\pm$ 8.0, n = 151). In the winter, mean flock size during the day was 13.8 $\pm$ 12.5, (n = 250), while at night only 5.5 $\pm$ 5.5, (n = 91) based on roost counts. The same pattern was observed in the spring, 5.8 $\pm$ 5.0 (n = 60) during the day versus 3.9 $\pm$ 2.6, (n = 15) at night. This difference in flock sizes between day and night is thought to be the result of small flocks coming together in common feeding areas during the day. The largest number of birds found roosting together in winter was 19.

The degree of integrity of smaller night groups is not clear. There was some shifting between groups as radioed individuals roosted together for several nights, but were apart on others. If social grouping existed it likely occurred in the smaller roosting flocks; however our data suggested that winter flocks appeared to be loosely bound.

Survival

Survival of prairie chicken cocks and hens was 66.6 (4 of 6) and 54.5% (6 of 11) respectively. Only individuals radioed as of 7 January were used to calculate winter survival. Of the 7 radioed prairie chickens found dead, 6 were fed upon by predators (5 by raptors and 1 by a mammal).

Home Range

Home ranges were calculated for all birds, but means only for those followed from the first week of January to 17 February. The mean winter home range for radioed prairie chickens was 8.4 km^2 (3.2 mi^2). Hens had slightly larger ranges than cocks and the ranges of immatures were larger than adults (Table 1).

Table 1. Mean home range sizes (sq km) for radio-tagged prairie chickens during winter, 15 December–17 February, Sheyenne National Grasslands, 1984-85.

Adult Hens	n= 7	8.7+4.6
Immature Hens	n= 2	9.3+3.2
Total Hens	n= 9	8.8+4.0
Adult Cocks	n= 4	7.2+3.2
Immature Cocks	n= 1	9.8+ -
Total Cocks	n= 5	7.7+4.1
TOTAL	n=14	8.4+3.6

Agriculture (private) and grassland (public) were represented in all home ranges. The ratio of grassland to agriculture was variable and ranged from 20:80 to 80:20. A mean of these ratios would be meaningless since each home range was a function of the distance between night roosting sites in grassland and feeding sites in agriculture. This distance varied for many individuals during the winter as snow conditions altered the availablity of food. Thus the proximity of available food to roosting areas controlled sizes of winter home ranges for prairie chickens on the SNG.

Individual birds moved most extensively in late December with the first snowfall, apparently searching for food sources. Once available food was located, birds established a regular pattern of use within the total winter home range. However, when new snow covered current source(s) of food, a shift in use pattern occurred. Some birds fed in only 1 or 2 fields all winter, but roosted in several areas.

MOVEMENTS

Winter to Spring

The mean maximum distance that radioed prairie chickens moved from winter to spring ranges (cocks to home booming ground hens to nest) was 4.4 km for cocks and 6.4 km for hens (Table 2). That cocks remained closer than hens to their home ground was also shown by the mean minimum distances moved (0.2 km for cocks and 3.2 for hens). Adult cocks, required no long seasonal movements as all remained within 5.0 km of their home booming ground.

Table 2. Mean distance moved (km) by radio-tagged prairie chickens from winter range (hens to nest and cocks to home booming ground), Sheyenne National Grasslands, 1984-85.

		Maximum	Minimum
Adult Hens	n=12	6.4+2.4	3.2+2.5
Immature Hens	n= 3	6.1+2.3	3.2+2.2
Total Hens	n=15	6.3+2.4	3.2+2.3
Adult Cocks	n= 4	4.0+0.3	0.2+0.1
Immature Cocks	n= 1	0.6+ -	0.3+ -
Total Cocks	n= 5	3.3+0.9	0.2+0.2
TOTAL	n=20	5.6+3.1	2.5+2.4

One immature cock moved 6.9 km (4.3 mi) from his eventual home booming ground, while covering a large area between three booming grounds in early March. He was known to have visited all three grounds, apparently in an effort to establish a territory. However, his home booming ground was only .6 km from his winter range.

Hens exhibited two general movement patterns in shifting from winter to spring range. Several hens wintered within 0.8 to 1.6 km of their spring ranges, while other hens moved considerable distances to eventual nest sites. Those which wintered close to spring ranges were in winter areas with more agriculture than grassland. Those which moved greater distances had spring areas characterized by large amounts of grass with little agriculture. It was felt the more extensive movements were related to winter food, with birds either returning to traditional food sources or moving until they found an adequate food source. More extensive moves made by adult hens suggested homing to the previous years nesting area. Two hens, followed during two springs, nested within 100 m of their previous years nests. Four other hens had nests which were found 2 years in a row (1 three) and all but one returned to nest near the same booming ground.

Movements made from winter to spring by adult hens were made quickly (1-2 days), were directional with no wandering, and each hen localized very soon near their eventual nest site. Three immature hens followed to nests showed no rapid movements that suggested homing. They also localized later and more slowly than adult hens.

Relationship to Booming Grounds

Winter distribution of prairie chickens on the SNG coincided closely with that of the booming grounds; for the most part, all birds remained within 3 km of a display ground. No radio-tagged prairie chickens were known to have left the SNG during the winter of 1984-85. All non-booming ground radio locations (n = 2444) and observations (n = 1985) of prairie chickens were within 6500 m (4 miles) of a known booming ground. The mean distance from radioed bird locations to nearest booming ground was 2007 ± 980 m in winter with 64.8% within 2400 m. The mean for non-radioed birds was 1921 ± 1001 m, with 68.1% within 2400 m. Radioed cocks in the winter were closer to booming grounds than hens (Table 3, Fig. 1),reflecting a strong association to their home ground. Evidence indicated that cocks attempted to stay as close to home ground as winter conditions and surrounding habitats permit. Hamerstrom et al. (1957) and Hamerstrom and Hamerstrom (1973) reported similar findings. Schwartz (1945) felt there was a "sphere of influence around each booming ground".

Hens showed much less association to a particular booming ground in winter than cocks, as only 49.5% of their locations were within 4000 m (2.5 miles) of their home booming ground (Mean = 4072 m, Table 3). Hens as a group showed little

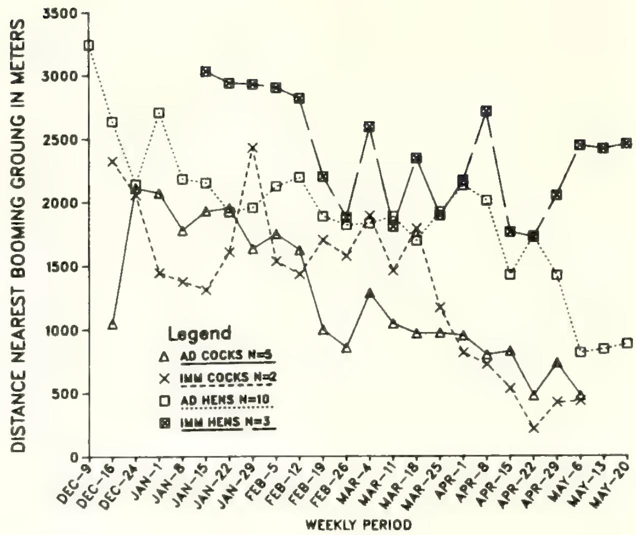

Figure 1.--Weekly mean distances to the nearest booming ground for radio-tagged prairie chickens, Sheyenne National Grasslands, 9 December-20 May, 1984-85.

affinity for their nest sites during the winter, with only 54.9% of the observations within 4000 m (2.5 mi). The mean distance to home booming ground decreased in early spring with cocks being closer than hens (1302 m vs 2004 m, Table 3). Both adult cocks and hens were closer than their immature counterparts (Table 3). No relationship was demonstrated between prairie chickens and the nearest sharptail dancing ground (Fig. 2).

The cocks returned to booming grounds in February, 1 radioed cock was observed on 5

Table 3.--Mean distance to nearest and home booming ground and nest for radio-tagged prairie chickens, Sheyenne National Grasslands, 1984-85. Number of locations in parentheses.

	Cocks			Hens		
	Adult N=4	Immature N=2	Total	Total	Adult N=12	Immature N=3
Distance Nearest Booming Ground						
Winter	1845± 713(582)	1661± 679(203)	1797± 709(785)	2327±1178(1659)	2140±1150(1251)	2900± 586(408)
Early Spring	1102± 689(185)	1631± 579(112)	1302± 697(297)	2004± 898(1116)	1886± 930(789)	2287± 745(327)
Distance Home Booming Ground						
Winter	2755±1127(582)	2030±1322(203)	2568±1222(785)	4072±1975(1373)	4282±2125(965)	3575± 967(408)
Early Spring	1424±1124(185)	1941±1078(112)	1619±1133(297)	3662±1974(1104)	3889±2140(777)	3122±1373(327)
Distance Nest						
Winter				4299±2144(1283)	4426±2383(875)	4026±2001(408)
Spring				3932±1960 (986)	4075±2374(659)	3643±1546(327)

February and 2 others on 10 February. Hens returned to home booming ground and nest areas in late March, and early April. Adult hens moved towards nests earlier and remained closer than immatures (Fig. 3).

A strong tendency existed for prairie chickens to remain in areas near a booming ground. During winter hens were nearer a booming ground than their nests (2327 m vs 4299 m). This suggests that the area within 3.2 km of any given booming ground is the key to prairie chicken habitat management. This area could serve as an effective management unit or a group of grounds as a complex in which management could focus its activities.

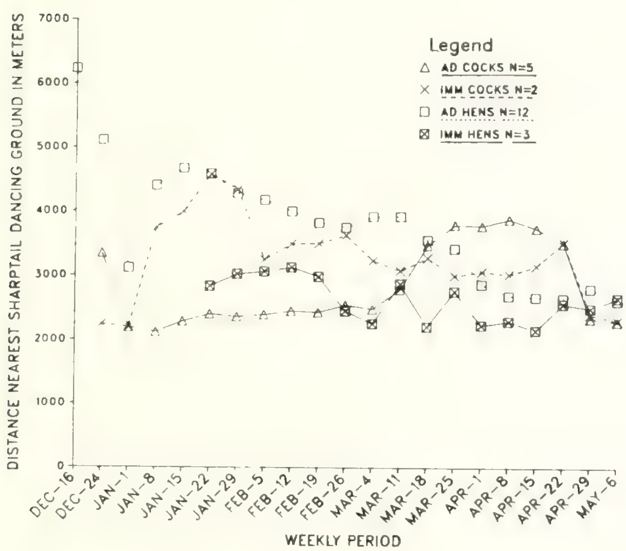

Figure 2.--Weekly mean distances to the nearest sharptail dancing ground for radio-tagged prairie chickens, Sheyenne National Grasslands, 16 December- 6 May, 1984-85.

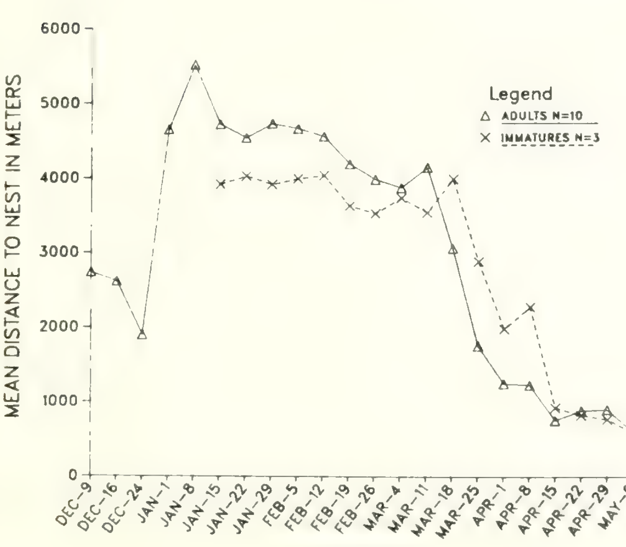

Figure 3.--Weekly mean distances to nest for radio-tagged prairie chicken hens, Sheyenne National Grasslands, 9 December-20 May, 1984-85.

Daily Movements

An index to daily movements was calculated by measuring the distance between day to night locations (DN), and the distance between consecutive night locations (NN). The DN distances, were close approximations of the distances moved between feeding and roosting areas and NN distances showed relative fidelity to the previous night's location.

DN Distance in winter were 1085 $\pm$ 778 m, (n = 852) and were greater for cocks than hens (1358 $\pm$ 909 m, n = 132 vs 1035 $\pm$ 855, n = 720). The greater DN movements for cocks is a result of morning visits to their booming grounds in the late winter. Conversely, hens centered their movements near feeding areas and showed no interest in booming grounds or nest sites during winter and early spring. The maximum distance moved from day to night in winter was 4 km (2.5 mi) for a cock and 4.4 km (2.7 mi) for a hen. Although DN movements were basically a measure of distances between feeding and roosting areas, not all birds used either the nearest available feeding area or the nearest roost.

After snow melted in early spring the DN movements for both cocks (1074 $\pm$ 938 m, n = 74) and hens (709 $\pm$ 584 m, n = 121) declined as food and cover became more available (Fig. 4). These early spring mean distances were 21% less for cocks and 32% less for hens than their respective winter means. The greater movements of cocks in early spring were due to their twice daily visits to booming grounds, plus flights to the agricultural areas to feed. Hamerstrom and Hamerstrom (1949) and Ammann (1957) also indicated that prairie chickens were most mobile during winter.

In early spring hens were not yet associated with a particular booming ground or their eventual nest areas and their movements were localized near their feeding areas. All radioed hens spent the first 4 weeks after snow melt moving only from roosting areas to feeding areas (less than 600 m) (Fig. 4). This reduction in movements may have allowed hens to recover lost weight.

Mean NN distances were 922 $\pm$ 770 (n = 445) in winter for hens and 949 $\pm$ 816 (n = 174) for cocks. With one exception, prairie chickens did not use the same roosting area on successive nights, the closest being 60 m. The exception involved 2 radioed birds which used the same roost area 3-4 nights in a row. These 2 birds spent most of the winter on private land and had only 3 undisturbed roost sites near their feeding areas. Their patterns were irregular, but they too shifted between 3 available roosting areas. This tendency to use several

roost areas in the winter points out the need for a good distribution of roosting cover.

Once snow melted, individuals began to use the same areas on successive nights (Fig. 5). Use of the same roost area on successive nights in spring may be due to an increase in security due to more available cover. Some of the same roosting areas used only once in the winter were used regularly on successive nights in the early spring.

Distances (NN) became less for cocks and hens as their activities become concentrated near their booming ground and nests in early April. The greatest NN distance for hens occurred during the last week in March when they moved from winter to spring areas (Fig. 5).

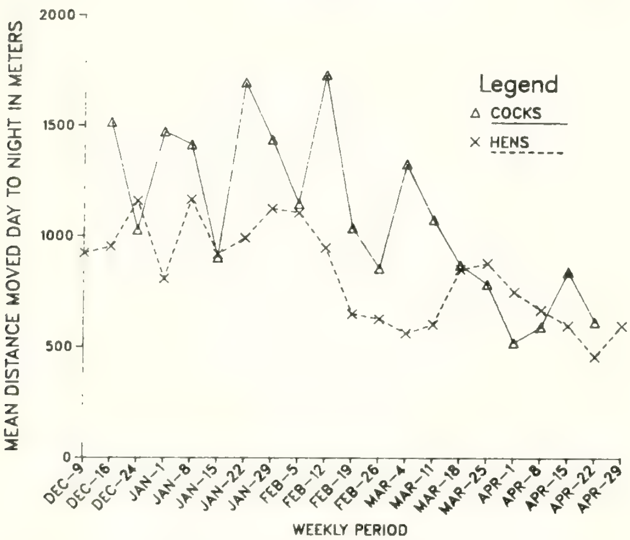

Figure 4.--Weekly mean distances moved from day to night for radio-tagged prairie chickens, Sheyenne National Grasslands, 9 December-5 May, 1984-85.

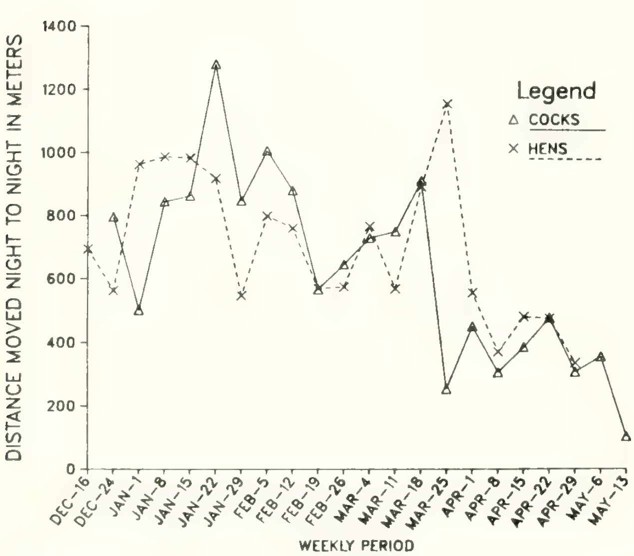

Figure 5.--Weekly mean distances between successive night locations for radio-tagged prairie chickens, Sheyenne National Grasslands, 16 December-13 May, 1984-85.

Cold and snow had the greatest influence on the daily movement patterns of prairie chickens. Fresh snow caused individuals to increase their within day movements when normal food sources were covered. Snow also caused abandonment of roost areas as new snow altered cover.

Prairie chickens responded to long periods of sub-zero temperatures by reducing activity. They remained in their roosts longer in the AM, fed in the agriculture later or during midday, flew to their roosts earlier than normal, (as early as 1400 hours) and remained in roost areas until the following day (15-17 hrs.). Visual documentation was obtained of individuals in snow burrows several hours before they would have gone to roost in milder weather or at other times of the year. Reduced activity during cold temperatures was thought to be an energy conservation mechanism. Hamerstrom and Hamerstrom (1949) observed similar behavior in prairie chickens during very cold or stormy weather in Wisconsin.

Habitat Use

Four major habitat components appear to determine the quality of prairie chicken habitat: type, height (form), disturbance and space (open treeless areas). All 4 are closely related to one another and most are more closely associated with cover structure than species composition. Height or form appeared to be the critical component as it creates the structure that prairie chickens actually use. This is not new, but is based on the life form concept as applied to prairie chickens by Hamerstrom et al. (1957) and Jones (1963). From a management perspective, disturbance is the key factor as it determines height, and influences the amount and distribution of cover.

A total of 3674 radio locations of prairie chickens from 15 December - 15 March were used in habitat analyses. Booming ground observations and unknown habitat types were excluded. Tree(s) were not included in the analysis of height and disturbances. No effort was made to analyze habitat use relative to the amount available in the study area. Observations in the field showed that the total amount of a habitat type available did not determine use and was not a valid index to what prairie chickens preferred. These indicies or importance values relate only to conditions under which they were collected and do not take into account the habitat needs of animals during other critical times (nesting, brood rearing). To be effective management must relate winter use to the habitat used at other times of the year.

Overall, the agriculture and grass habitat types totaled 71.3% of the habitat used by radio-

tagged prairie chickens in the winter of 1984-85, on the SNG. Other studies indicated similar habitat use patterns (Schwartz 1945, Grange 1948, Hamerstrom and Hamerstrom 1949, Baker 1953, Ammann 1957, Hamerstrom et al 1957, Mohler 1963, Robel et al. 1970a, and Horak, 1985). A breakdown by habitat type showed that agriculture made up 41.7% of the total use, grass 29.6%, followed by trees and shrubs at 9.0 and 7.6%. (Table 4).

Corn (picked and silage) made up 70.8% of the agricultural types followed by oats and sunflowers at 8.6 and 8.0%. These difference are misleading as not all birds had all of the agricultural types available within or near their ranges. Some individuals used corn all winter, while others used corn and/or sunflowers.

Habitat use varied with time of day (Fig. 6). Use of agriculture by prairie chickens occurred primarily during the AM and PM and was associated with feeding and loafing. Habitat used for night roosting was dramatically different from daytime use as there was a complete shift away from the agricultural habitat types. Night roosting occasionally occurred in agriculture, but was not common. The majority of night locations occurred in grassland followed by shrubs, and wetlands (Table 4). The lowlands received the greatest use, followed by reed canary (*Phalaris arundinacea*), midland grasses, primarily little bluestem, and quackgrass (*Andropyron repens*). All of these grasses are tall in form, and stand up well against winter conditions. Almost all of the

Table 4.--Habitat type use by time of day (%) for radio-tagged prairie chickens, winter (9 December-17 February) and early spring (18 February-15 March), Sheyenne Grasslands, 1984-85. Number of locations in parentheses.

	Winter					Early Spring				
	Time of Day						Time of day			
Habitat Type	AM	Midday	PM	Night	Total	Total	AM	Midday	PM	Night
Agriculture	78.9(491)	31.0(215)	50.8(229)	3.8 (20)	41.7 (955)	43.6 (603)	78.1(250)	23.8 (88)	70.4(236)	8.1 (29)
Picked corn	47.4(234)	67.9(146)	57.2(131)	60.0 (12)	54.8 (523)	47.9 (289)	48.0(120)	37.5 (33)	55.1(130)	20.7 (6)
Silage corn	16.7 (82)	13.5 (29)	18.3 (42)	0	16.0 (153)	11.8 (71)	15.2 (38)	6.8 (6)	11.4 (27)	0
Oats	10.2 (50)	4.7 (10)	7.9 (18)	20.0 (4)	8.6 (82)	1.7 (10)	2.0 (5)	1.1 (1)	1.7 (4)	0
Sunflowers	10.0 (49)	3.3 (7)	8.7 (20)	0	8.0 (76)	18.2 (110)	24.4 (61)	17.0 (15)	14.4 (34)	0
Soybeans	9.0 (44)	0.9 (2)	5.7 (13)	0	6.2 (59)	0.3 (2)	0.4 (1)	0	0.4 (1)	0
Alfalfa	3.5 (18)	5.1 (11)	1.3 (3)	20.0 (4)	3.6 (36)	20.1 (121)	10.0 (25)	37.5 (33)	16.9 (40)	79.3 (23)
Haystack	2.9 (14)	4.7 (10)	0.9 (2)	0	2.7 (26)	0	0	0	0	0
Grass	9.3 (58)	25.5(177)	21.1 (95)	66.7(350)	29.6 (680)	37.6 (520)	12.2 (39)	37.8(140)	18.2 (61)	78.4 (280)
Lowland	39.7 (23)	35.6 (63)	45.3 (43)	64.0(224)	51.9 (353)	52.1 (271)	38.4 (15)	25.0 (35)	31.1 (19)	72.1 (202)
Grass Forbs	13.8 (8)	17.5 (31)	10.5 (10)	6.6 (23)	10.6 (72)	13.5 (70)	0	22.9 (32)	18.0 (11)	9.6 (27)
Reed Canary	17.2 (10)	23.7 (42)	15.8 (15)	13.7 (48)	16.9 (115)	9.2 (48)	5.1 (2)	8.6 (12)	4.9 (3)	11.1 (31)
Midland	6.9 (4)	8.5 (15)	5.3 (5)	7.4 (26)	7.4 (50)	13.8 (72)	35.9 (14)	30.9 (43)	16.4 (10)	1.8 (5)
Upland	8.6 (5)	6.2 (11)	18.9 (18)	1.2 (4)	5.6 (38)	4.0 (21)	12.8 (5)	2.9 (4)	19.7 (12)	0
Prairie Hay	3.4 (2)	2.8 (5)	3.2 (3)	0	1.5 (10)	2.9 (16)	7.7 (3)	5.7 (8)	8.2 (5)	0
Quackgrass	10.3 (6)	5.6 (10)	1.1 (1)	7.1 (25)	6.2 (42)	4.2 (22)	0	4.3 (6)	1.6 (1)	5.4 (15)
Edge type	2.6 (16)	14.6(101)	6.9 (31)	1.0 (5)	6.8 (153)	6.6 (91)	3.4 (11)	15.1 (56)	4.5 (15)	2.5 (9)
Fencelines	81.3 (13)	72.3 (73)	61.3 (19)	80.0 (4)	71.3 (109)	57.8 (52)	36.4 (4)	69.6 (39)	46.7 (7)	22.2 (2)
Railroad	6.3 (1)	16.8 (17)	16.1 (5)	20.0 (1)	17.0 (24)	31.9 (29)	54.5 (6)	23.2 (13)	53.3 (8)	22.2 (2)
Upland Shrub	12.5 (2)	10.9 (11)	22.5 (7)	0	9.2 (20)	11.0 (10)	9.1 (1)	7.1 (4)	0	55.6 (5)
Trees & edges	6.1 (38)	15.7(109)	10.6 (48)	2.3 (12)	9.0 (207)	7.8 (108)	4.3 (14)	17.0 (63)	5.7 (19)	3.4 (12)
Shelterbelts	18.4 (7)	28.4 (31)	12.5 (6)	0	43.5 (44)	75.9 (82)	64.3 (9)	85.7 (54)	63.2 (12)	58.3 (7)
Sandhills	47.4 (18)	17.4 (19)	50.0 (24)	100.0 (12)	35.3 (73)	14.8 (16)	28.6 (4)	6.3 (4)	21.1 (4)	33.3 (4)
Tree(s)	34.2 (13)	54.1 (59)	37.5 (18)	0	43.5 (90)	9.3 (10)	7.1 (1)	7.9 (5)	15.8 (3)	8.3 (1)
Shrubs	1.9 (12)	10.2 (71)	6.7 (30)	11.8 (62)	7.6 (175)	2.7 (37)	1.6 (5)	4.1 (15)	0.3 (1)	4.5 (16)
Snowberry	58.3 (7)	39.4 (28)	86.7 (26)	95.2 (59)	68.6 (120)	59.5 (22)	0	40.0 (6)	0	100.0 (16)
Misc Shrubs	41.7 (5)	42.6 (30)	13.4 (4)	3.2 (2)	23.4 (41)	16.2 (6)	20.0 (1)	26.7 (4)	100.0 (1)	0
Shrub Grass	0	18.3 (13)	0	1.6 (1)	8.0 (14)	24.3 (9)	80.0 (4)	33.4 (5)	0	0
Forbs	0.5 (3)	1.2 (8)	0.7 (3)	7.6 (40)	2.4 (54)	0.1 (1)	0	0.3 (1)	0	0
Misc Forbs	100.0 (3)	87.5 (7)	33.3 (1)	27.5 (11)	40.7 (22)	0	0	0	0	0
Sweet Clover	0	12.5 (1)	66.6 (2)	72.5 (29)	59.3 (32)	100.0 (1)	0	100.0 (1)	0	0
Wetland	3.3 (2)	0.9 (6)	1.6 (7)	6.7 (35)	2.2 (50)	0.9 (12)	0.3 (1)	0.8 (3)	0.3 (1)	2.0 (7)
Other	0.3 (2)	1.0 (7)	1.8 (8)	0.2 (1)	0.8 (18)	0.7 (10)	0	1.1 (4)	0.6 (2)	1.1 (4)
Total	100.0(622)	100.0(694)	100.0(451)	100.0(525)	100.0(2292)	100.0(1382)	100.0(320)	100.0(370)	100.0(335)	100.0(357)

shrub use occurred in snowberry (Symphoricarpos occidentalis).

Manske and Barker (1981) reported budding by prairie chickens in shelter belts on the SNG in 1980. In this study budding was rarely observed and the primary use of trees appeared to be for loafing before the birds moved into or after they left the agricultural fields. The main food source on the SNG for prairie chickens in winter was provided by agriculture on private land. There was no agricultural land on the SNG public land.

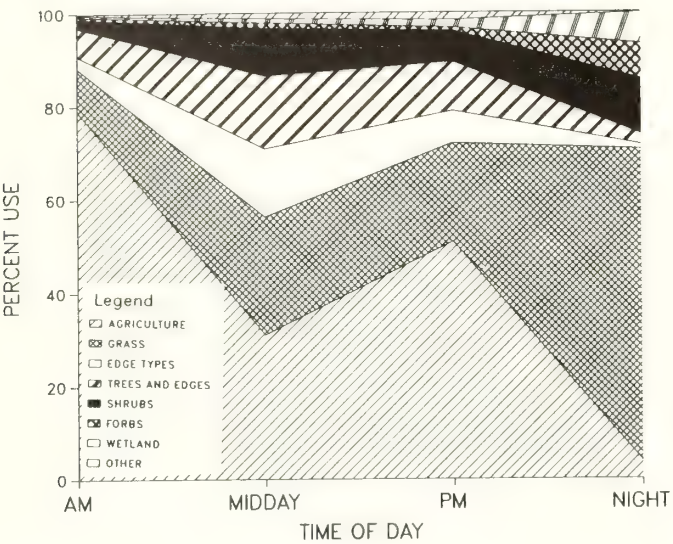

Figure 6.--Use of habitat types by time of day for radio-tagged prairie chickens during winter, 15 December-17 February, Sheyenne National Grasslands, 1984-85.

Height

Of all the radio locations in winter, 78% were associated with Class II or taller vegetation. Class III vegetation (25-50 cm) dominated the usage at 60%. The pattern of use, like that for habitat type, varied between the periods of the day (Fig. 7). The shorter forms, Class I and II were used primarily during the AM (51.4%) with slightly lower use during the PM (47.2%). The taller Classes (III and IV) were used for day roosting during the midday period (59.6%). Robel et al. (1970a) indicated that density (visual obstruction) was not a "significant factor in habitat usage in prairie chickens". However, their density data were collected from vegetation transects and not from the specific sites used by prairie chickens. Most other researchers have pointed out, the importance of taller undisturbed cover (Hamerstrom and Hamerstrom 1949, Baker 1953, Ammann 1957, Hamerstrom et al. 1957, Horak, 1985).

The edge habitats between shorter and taller vegetation classes were used equally through the day. This edge type was important and probably used more than our data indicates as it provided simultaneous access to 2 vegetation forms. This occurred along the borders of agricultural fields, and edges between lowland and upland and upland and midland grasses. Feeding was observed most in the lower height classes, particularly Class I (81.8%). Day roosting was primarily associated with Classes III and IV (greater than 25 cm), with most occurring in Class III (63.0%). The high use of the lower classes reflected the bias that activity must be observed to be documented and birds were more easily seen in the shorter vegetation types. However, telemetry data showed the same general pattern of use and indicated that birds were most active, primarily feeding in the AM and PM. The day roosting observations were based on birds flushed or examination of sign after birds moved and was thought to accurately represent day roosting habitat and height use. The increased use of the taller classes during the PM period coincides with observations of prairie chickens going to roost early during periods of cold weather.

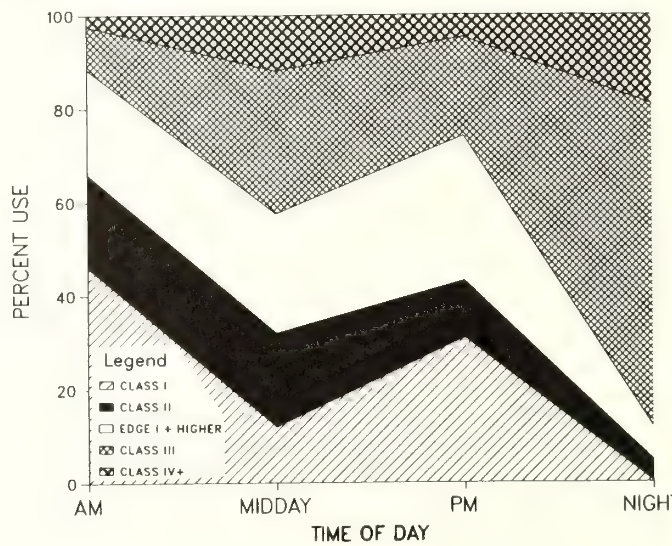

Figure 7.--Use of cover by height classes (I=0-8 cm, II=9-25 cm, III=26-50 cm, IV+ greater than 50 cm) by time of day for radio-tagged prairie chickens during winter, 15 December-17 February, Sheyenne National Grasslands, 1984-85.

Disturbance

Disturbance has its greatest influence on vegetation height. The taller height classes were used most by prairie chickens, yet shorter forms were used for feeding. A mixture of tall and short, or undisturbed and disturbed, is an important aspect of prairie chicken habitat. The amount and distribution of each will strongly influence the number of prairie chickens in a given area. Large amounts of disturbed short vegetation will reduce the amounts available for roosting and nesting. The most difficult component of prairie chicken habitat to maintain is the

undisturbed open grassland, since this is the type of habitat most commonly converted to cropland or pastureland.

Use by prairie chickens of disturbed or undisturbed habitat also varied during the day and showed a strong similarity in pattern of use to type and height data. Disturbed agricultural areas were used most during the AM (82%) and less during PM (58.5%) (Fig. 8). This high use of agricultural habitats with their shorter height classes reflected a concentration of available food. Open low vegetation provided easier access to food on the ground and agricultural activities increased both the distribution and amount present. This use of disturbed areas has also been reported by (Yeatter 1943, Ammann 1957, and Drobney and Sparrowe 1977).

Use of undisturbed cover was highest at night (77.9%, Fig. 8). Unmowed lowlands (38.7%) and lightly grazed lowlands were used most often at night for roosting. Hamerstrom et al. (1957) suggested that prairie chickens when night roosting have a preference for grass and sedges over woody cover. Snowberry was used 11.2% and classified as undisturbed even though areas between stems were heavily grazed. The stucture and height created by snowberry was similar to undisturbed grassland but was used only for snow roosting when it trapped enough snow to permit burrowing.

All of the unmowed lowlands were at least lightly grazed since cattle were in all pastures at sometime during the grazing season. These lowlands were also classified as undisturbed as use by cattle on the SNG rarely reduced structure. By contrast mowing of lowlands in the summer eliminated all structural cover from these areas until the following June.

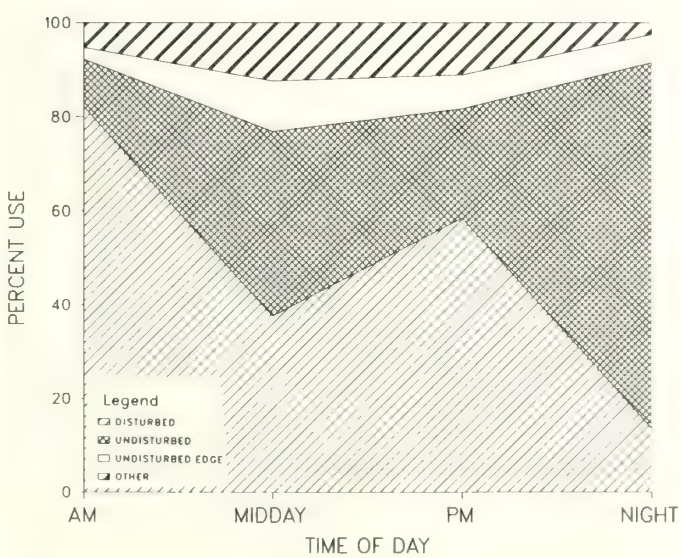

Figure 8.--Use of habitat by disturbance types by time of day for radio-tagged prairie chickens during winter, 15 December-17 February, Sheyenne National Grasslands, 1984-85.

Land Ownership

Habitat use based on land ownership showed that 76.4% of all radio locations occurred on private land, due primarily to high use (52.9%) of agriculture during the day. Night roosting favored public land (56.2% vs 43.8%). The use of private and public land emphasized the importance of both to winter survival of prairie chickens on the SNG. The recorded use of private land for roosting was the result of 2 radioed prairie chickens that used private lands for both feeding and roosting. These roosting areas, like those on the SNG, were lowland pasture areas that were undisturbed, Class III and IV vegetation, a habitat not common on private land. The typical pattern of 17 of 20 radioed birds was to feed on private agricultural land and roost at night on public land.

Early Spring

Habitat use relative to type, height and disturbance patterns in early spring were only slightly different from those observed during winter. The use of grass increased from 29.6% in winter to 37.6% in early spring. The use of edge types remained the same and the use of shrubs declined (Table 4). Changes in the daily pattern of habitat use occurred in the PM period, where the incidence of agriculture increased from 50.8% in the winter to 70.4% in the spring. The use of the lower height classes in the PM also increased in early spring (63.1% vs 81.7%) as did the use of disturbed habitat (58.5% vs 77.3%). These changes were the result of longer warmer days and prairie chickens spent more time feeding in the PM.

Use of night roosting habitat in spring was similar to winter, as the lowlands and Class III vegetation still dominated (71% vs 66%). Overall use by land ownership remained the same except for a reduction in use of public land in the PM, a reflection of the longer feeding periods in agriculture in the PM.

Within the agricultural types, the use of alfalfa and sunflowers increased from winter to spring from 3.6-20.1% and from 8-18.2% respectively. The disappearance of snow made food in these 2 types available. Prairie chickens showed a preference for sunflowers when both corn and sunflowers were in the same feeding field. In winter, harvested sunflowers were only available where snow was blown clear.

Alfalfa was used for both feeding and roosting in spring. The alfalfa fields used for roosting (both day and night) were fields where only 2 crops were taken and regrowth in late summer produced cover of 8-15 cm. Short-cropped alfalfa was used for feeding as the growing green vegetation was apparently attractive to prairie chickens, particularly hens.

Winter and early spring habitat data presented here should not be taken out of context. The high use of agriculture was important to the survival of the prairie chicken on the SNG, but it must be related to the bird's year-long needs. Management must provide a combination of agriculture and grass that will provide the necessary year-long requirements. The grass component must be of the right height and type for nesting and roosting, and occur in proximity to winter food. From early spring on there is a decided decrease in the use of agricultural types and a corresponding increase in the use of grassland. Over 70% of all nests and over 90% of all booming grounds were located on the public grasslands. Although this phase of the study was concerned primarily with winter habitat, a decided change in use was noted between winter and late spring. Habitat use by type, height class disturbance and landownership on a weekly basis, by day and night, are presented in Figures 9-16. After the first week of April, a day time shift in habitat use was recorded, from agriculture to grassland. Night roosting continued to be centered in the undisturbed lowlands.

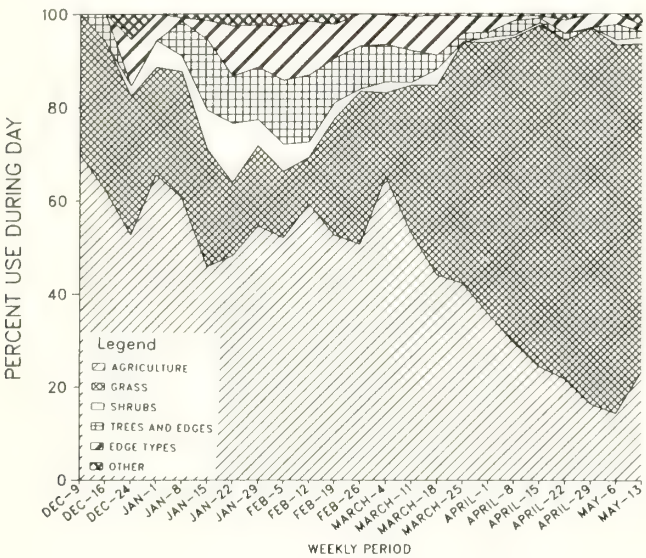

Figure 9.--Weekly use of habitat types during the daytime for radio-tagged prairie chickens Sheyenne National Grasslands, 9 December-19 May, 1984-85.

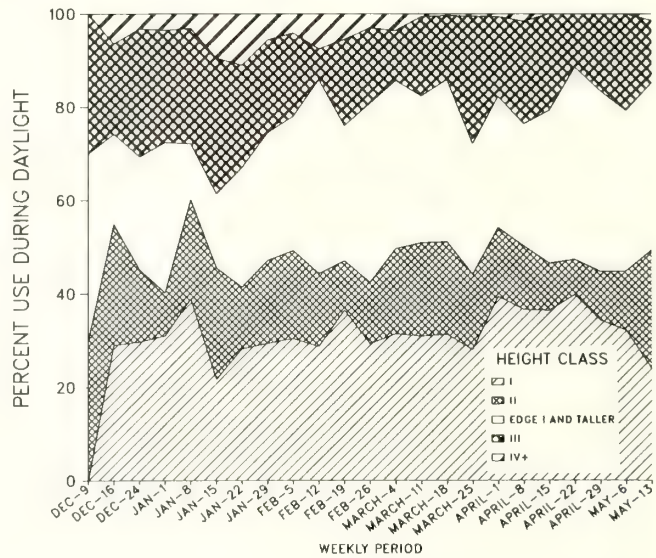

Figure 11.--Weekly use of cover by height classes (I=0-8 cm, II=9-25 cm, III=26=50 cm, IV+= greater than 50 cm) during the daytime for radio-tagged prairie chickens, Sheyenne National Grasslands, 9 December-19 May, 1984-85.

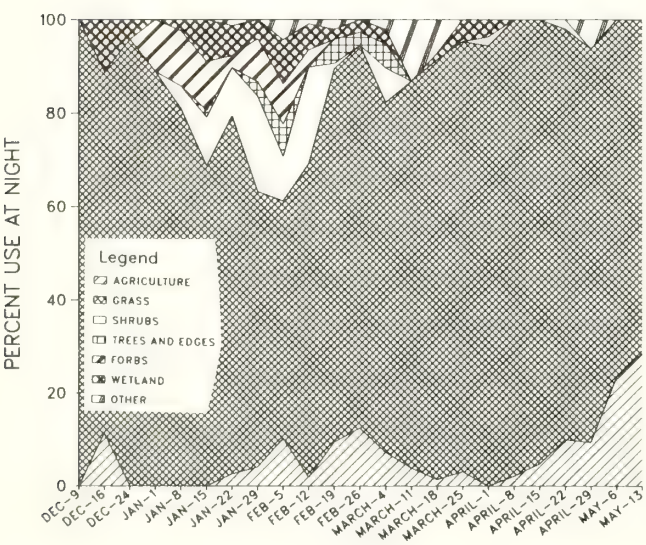

Figure 10.--Weekly use of habitat types at night for radio-tagged prairie chickens, Sheyenne National Grasslands, 9 December-19 May, 1984-85.

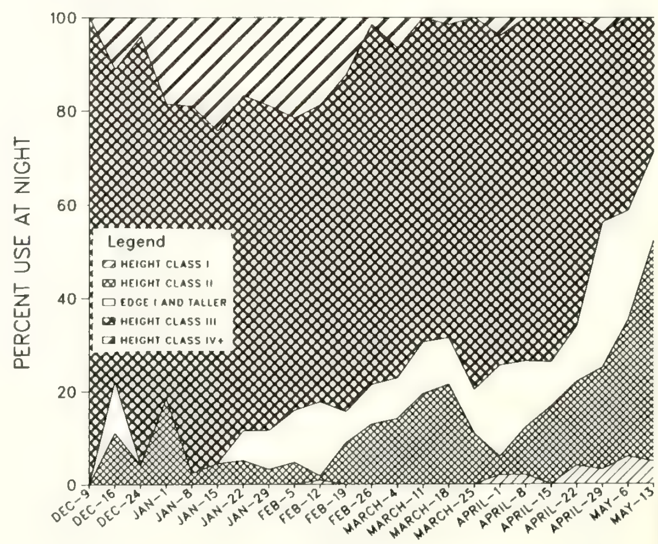

Figure 12.--Weekly use of cover by height classes (I=0-8 cm, II=9-25 cm, III=26=50 cm, IV+= greater than 50 cm) at night for radio-tagged prairie chickens, Sheyenne National Grasslands, 9 December-19 May, 1984-85.

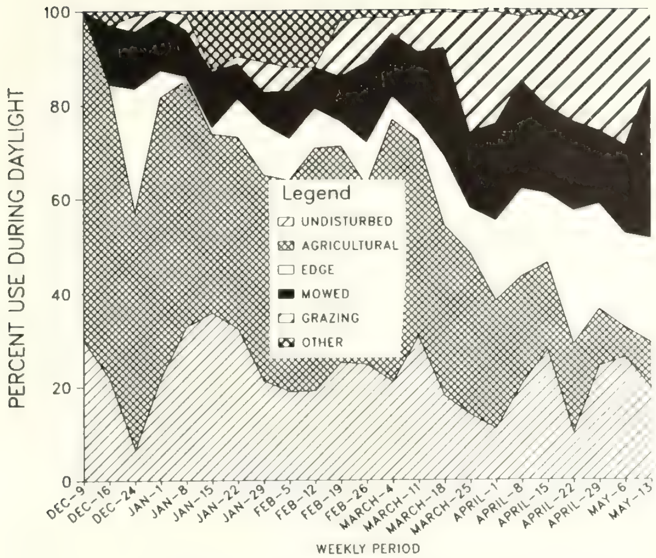

Figure 13.--Weekly use of habitat by disturbance types during the daytime for radio-tagged prairie chickens, Sheyenne National Grasslands, 9 December-19 May, 1984-85.

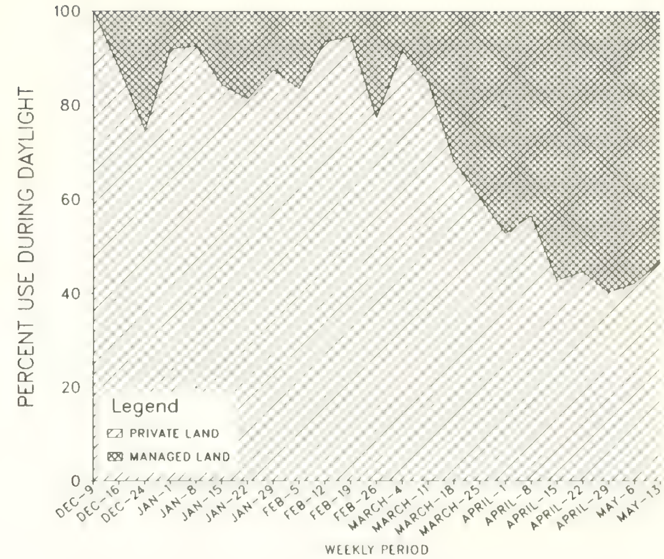

Figure 15.--Weekly use of land types during the daytime for radio-tagged prairie chickens, Sheyenne National Grasslands, 9 December-19 May, 1984-85.

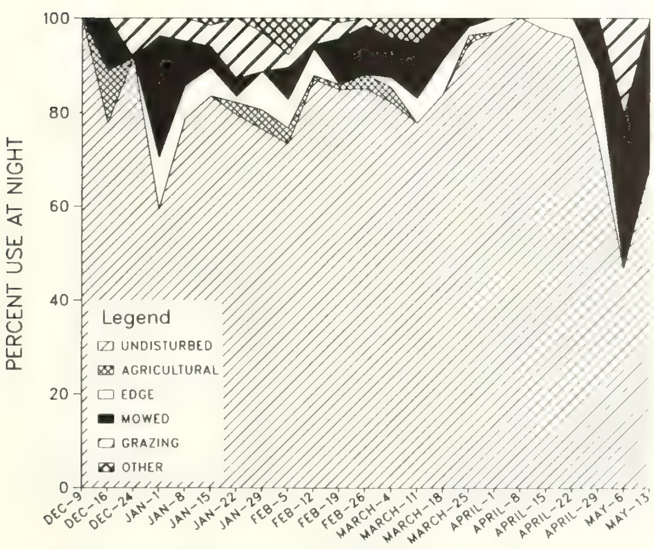

Figure 14.--Weekly use of habitat by disturbance types at night for radio-tagged prairie chickens, Sheyenne National Grasslands, 9 December-19 May, 1984-85.

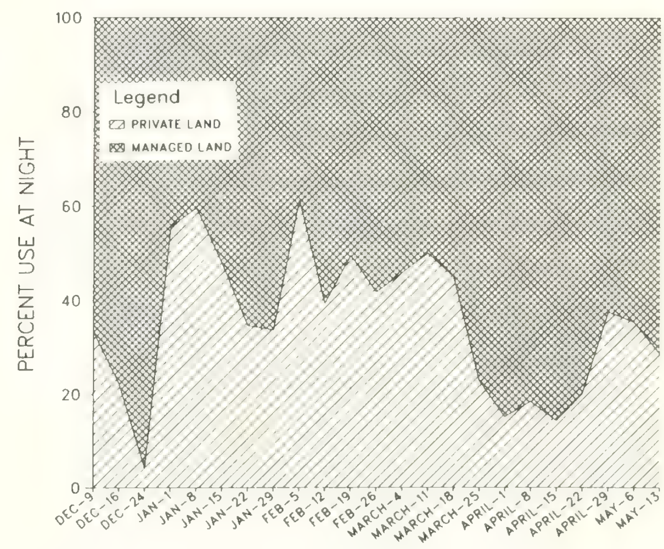

Figure 16.--Weekly use of land types at night for radio-tagged prairie chickens, Sheyenne National Grasslands, 9 December-19 May, 1984-85.

Summary Daily Pattern

The daily tracking of radioed individuals, along with observations in the field, yielded the following general pattern for winter daily movements and habitat use by prairie chickens on the SNG. Prairie chickens left the roost area in small flocks, after sunrise, flew 0.8-1.6 km to agricultural fields where they fed and loafed in low form (Class I or II, 0-25 cm) disturbed vegetation, primarily corn. They walked or flew 0.8-1.6 km to taller, (Class III, 26-50 cm) undisturbed vegetation, where they loafed or day roosted during midday. They returned to short form, disturbed vegetation in the PM, fed and flew to taller (Class III or IV) undisturbed lowlands or snowberry to night roost. Prairie chickens typically made 4 major flights of over 0.4 km (.25 mile) per day, 1 from roosting to feeding, 1 to day roost areas, 1 back to the feeding area and a final flight to a roosting area. Flights to feeding and roosting areas were often made in 2 segments, 1 long and 1 short, making 6 flights a day. Changes in the daily pattern usually occurred only when new snow covered regular feeding areas, or when sub-zero temperatures caused them to spend

more time in the roost. This pattern changed for the cocks in late winter as they initiated visits to their booming grounds early in the morning before they fed. Hens reduced their movements and localized near a food source. As spring progressed cocks visited booming grounds in the morning and evening, and eventually abandoned agriculture and began to feed in the grasslands near their booming grounds.

Individual Night Roosts

A total of 372 winter and 52 early spring prairie chicken night roosts were examined and analyzed between 12 January and 15 March in 1985. Four types were documented: a vegetation roost, where vegetation was the only source of cover; a snow depression, where the bird made a bowl in the snow and snow was the main source of cover (Fig. 17); a snow vegetation-roost where both vegetation and snow provided cover; and the snow burrow where the bird made a tunnel and enclosed cavity into soft snow (Fig. 18).

Both the accumlation or the movement of snow by wind created situations that influenced roost site selection. With the exception of several snow burrows in the sandhills where the birds burrowed into snow that had accumulated in drifts of up to 2 meters, all observed roosts were associated with some type of vegetation. The vegetation either served as cover or caused snow to accumulate in a snow fence effect. Terrain served a similar function as blown snow accumulated in the lee of ridges.

Evaluating the cover at individual roost sites was difficult when snow was present, as the birds used both snow and vegetation. Because of the role snow played in providing roost cover, the Robel pole was used to evaluate total coverage and coverage by vegetation. Total coverage included snow and vegetation in reading obstruction on the Robel pole, while coverage by vegetation included vegetation only. Each roost had 4 Robel pole readings, but because of snow, some had from none to 4 for vegetation.

Dominant Cover

No detailed species composition was collected at individual roost sites, as only the dominant species or genus was visually estimated for each roost (Table 5). Grasses and sedges were dominant at 74% of the roosts in winter. Panicum vergatum and Carex lanuginosa and Panicum sp. and Carex sp. either alone or in combination, were dominant at 43.6% of the observed roosts. Snow burrows were associated with the taller species that trapped and accumulated enough snow to permit the birds to burrow. Snowberry, sweet clover, quackgrass, Panicum spp. and Spartina gracilis, all tall, sturdy species dominated at snow burrows.

Figure 17.--Snow depression used for night roosting by prairie chicken, Sheyenne National Grasslands, 1984-85.

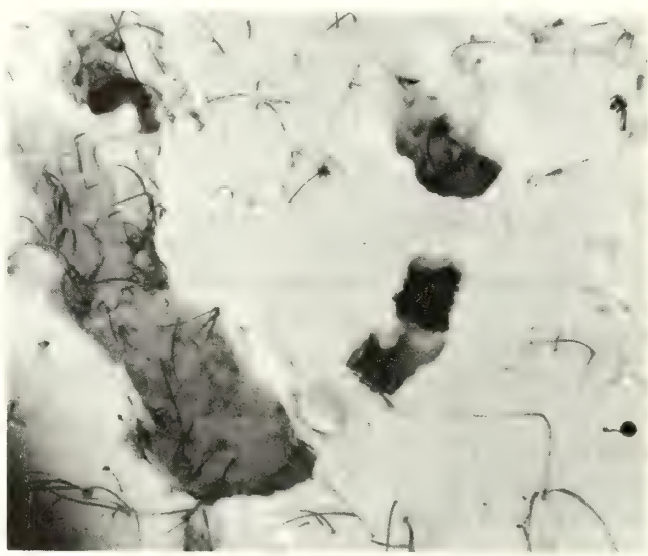

Figure 18.--Snow burrow used for night roosting by prairie chicken, Sheyenne National Grassland, 1984-85.

Dense cover was not used for roosting or burrowing as the density of stems prevented entry into the vegetation. Space between stems is necessary to permit burrowing, but height and structure are also necessary to hold or accumulate snow. Snowberry and sweetclover (Melilotus spp.) were not important dominants in any other roost types as they provided little cover in the absence of deep snow.

To snow burrow the birds actively sought areas where snow had accumlated to the necessary depth. Birds commonly attempted to snow burrow only to have it collapse. Snow burrows were often

Table 5.--Percent occurrence of dominant plant species at prairie chicken night roosts, winter (9 December-17 February) and early spring (18 February-15 March), Sheyenne National Grasslands, 1984-85. Number of roosts in parentheses.

	Winter					Early Spring
	Type of Roost					Type of Roost
Species	Vegetation	Vegetation and Snow	Snow Burrow	Snow Depression	Total	Vegetation
Panicum vergatum	7.7 (3)	9.2(10)	2.6 (4)	5.5 (7)	5.6 (24)	9.5 (6)
Panicum spp.	12.8 (5)	2.8 (3)	13.6(21)	15.7(20)	11.4 (49)	
Carex lanuginosa	12.8 (5)	3.7 (4)	3.8 (6)	3.1 (4)	4.4 (19)	30.2 (19)
Carex spp.		36.7(40)		13.3(17)	13.3 (57)	9.5 (6)
Panicum/Carex spp.	7.7 (3)	29.4(32)	2.6 (4)	3.9 (5)	10.2 (44)	9.5 (6)
Andopyron repens		3.7 (4)	7.1(11)	10.2(13)	6.5 (28)	7.9 (5)
Phalaris arundinacea	51.3(20)	1.8 (2)		2.4 (3)	5.8 (25)	
Calamagrostis inexpansa	2.6 (1)	3.7 (4)			0.9 (5)	1.6 (1)
Brommus inermis			0.6 (1)	1.6 (2)	0.7 (3)	
Andropogon gerardi						9.5 (6)
Spartina gracilis		6.4 (7)		1.6 (2)	2.1 (9)	
Andropogon scoparius			11.0(17)	5.5 (7)	5.6 (24)	
Melilotus spp.			14.9(23)	7.1 (9)	7.5 (32)	
Symphoricarpos occidentalis			19.5(30)	13.4(17)	11.0 (47)	
Salix spp.	2.6 (1)		4.5 (7)		1.9 (8)	1.6 (1)
Aster sp.			5.8 (9)	1.6 (2)	2.6 (11)	
Solidago spp.			2.6 (4)	1.6 (2)	1.4 (6)	1.6 (1)
Typha sp.				0.8 (1)	0.2 (1)	
Poa sp.	0.6 (1)				0.5 (2)	
Sorghastrum nutans			5.8 (9)	2.4 (3)	2.8 (12)	
Corn		2.8 (3)	1.9 (3)	.8 (1)	1.6 (7)	
Alfalfa				9.5(12)	2.8 (12)	19.0 (12)
Open snow					3.2 (5)	
Total	39	109	150	134	437	63

unsuccessful either because the snow was too shallow or too soft to support a roof (Fig 19).

All successful burrows during the winter 1984-85 were in areas where snow had accumulated due to vegetation or terrain. When a bird failed in its attempt to burrow, it usually walked a short distance and formed a snow depression near some vegetation above the snow. At times both snow burrows and snow depressions were found in the same group of roosting birds.

Unused snow depressions were often found in the tracks leading to eventual night roosts. These depressions contained 1-2 or no droppings and appeared to be temporary or possibly even unsatisfactory roosts as birds left them and moved to a burrow or another depression farther away. At times some birds must have flown to different sites because no tracks were found leading from the unused depression. These depressions may have been loafing forms occupied only until the bird went to roost for the night, although, at times the bird remained for the night in their first and only depression. Back tracking from night roosts has revealed as many as three depressions on the way to the final night roost. The mean distance walked in snow to night roosts was 104 ± 84 m (n = 101).

No evidence was found that prairie chickens ever dove from flight into snow burrows. The usual pattern (based on tracks) was to land in open areas along the edge of vegetation, walk (0.1-20 m) into cover and select a roost site. In the morning birds either flew directly from their roosts or walked a short distance and flew. Tracks indicated that birds did little feeding in roost areas in the morning, although some feeding occurred in the evening prior to roosting.

Figure 19.--Unsuccessful attempt at snow burrowing by prairie chicken, Sheyenne National Grasslands, 1984-85. (E=entrance, P= snow plug sealing entrance).

Fox and coyote tracks were often observed in roost areas and at times they passed within 10 m of roosting birds during the night. Of the 372 winter roosts observed, there was no evidence that any birds were killed or flushed at night.

Effective Cover

The use of snow as cover appears to serve primarily as wind shelter and/or insulation. Mean coverage by vegetation ranged from 1.1-3.8 and total coverage (including snow) varied between the types of night roosts (Table 6). Total coverage and vegetation coverage were higher in the winter than early spring. Analysis of 368 random points in the same habitat as the roosts suggested that roosting prairie chickens selected sites in winter with greater total and vegetation coverage and deeper snow. The selection of taller cover continued into the early spring (Table 7).

Height Class

Class III (25 to 50 cm) or taller residual vegetation was associated with 94.1% of all roost types (Table 7). Comparisons with random height classifications, indicated that prairie chickens selected the taller classes within the areas they used (CSq, $P = 0.001$, df = 3). A breakdown by disturbance types, shows that 78% of observed roosts were in undisturbed habitat, and 68% of these were in unmowed lowlands. Uplands or mowed lowlands were not used in winter or early spring.

Night roosts were usually located in the open, away from tree(s). Mean distance to the nearest single tree in winter was 320±221 (n = 485) and to nearest trees (woodlot or clump) 353±241 (n = 485). The birds roosted farther from trees in spring than winter. (503±354 m, n = 33 vs 353±241, n = 485). They roosted near the edge of cover in both winter (18.1±20.5 m (n = 405) and spring (14.7± 10.4 m, n = 50). The nearest edge in both spring and winter was typically a lower height Class (91%) and 83% of the edge types were heavily grazed or mowed. Roosting flocks confined themselves to a small portion of a roost area as average maximum distance between roosting birds was 27.9±15.8 (n = 94) in the winter and 11.5±27.4 m, (n = 24) in the spring. The average distance to nearest bird showed the same pattern as birds roosted closer to each other in spring 1.7±1.3 (n = 36) than in the winter, 3.3±5.6 (n = 261). The greater distances from the edge and between birds in winter was thought to be due to less cover above the snow, causing the birds to spread out over a larger area to find suitable cover or snow.

Size

Even though prairie chickens clustered when night roosting and remained near the edge, they

Table 6.--Mean Robel pole readings by total and vegetation coverage for individual prairie chicken night roosts and random points, during winter (9 December–17 February), and early spring (18 February-15 March), Sheyenne National Grasslands, 1984-85.

	Mean Robel pole reading			
	Total Coverage*	Total Coverage	Coverage by Vegetation	Coverage by Vegetation
Roost Type	Roosts	Random Points	Roosts	Random Point
Vegetation				
Spring	1.6±1.0 (40)	1.2±1.2 (97)	1.6±1.0 (40)	1.2±1.2(97)
Winter	2.1±1.0 (32)	1.5±1.4 (46)	2.1±1.0 (32)	1.5±1.4(46)
Vegetation and snow				
Winter	2.8±1.4(115)	1.7±0.6 (56)	1.1±0.4 (90)	1.5±0.4(38)
Spring	1.9±0.5 (12)	1.3±0.5 (44)	1.9±0.5 (12)	1.3±0.5(44)
Snow Depression	2.1±0.8(120)	1.8±1.1(104)	3.2±0.9 (38)	2.4±1.1(12)
Unused Snow Depression	2.3±0.4 (76)		0 (76)	
Snow Burrow	2.6±0.8(145)	2.4±0.8 (162)	3.8±0.4 (2)	2.8±1.0 (7)
Unsuccessful Snow Burrow	2.2±0.6 (39)		0 (39)	

* Snow or vegetation or a combination of both.

roosted in relatively large undisturbed areas. The size of roost areas as determined by measurements from aerial photographs and in the field, showed that the mean size for 26 winter roost areas was 1.3 ha with a range of .04-5.5 ha; 76% were greater than 0.4 ha (1 acre) in size. Average length was 174±105 m and width 88±38 m. The larger areas were associated with private land or rough areas in the SNG that were not or could not be mowed. The size of the areas used in spring were smaller with a mean of 0.4±.28, (n = 7) (1 acre). Mean length and width were 82±39 m and 45.7±33 m).

Table 7.--Use of vegetation height classes (%) for observed prairie chicken roosts and random points during winter (9 December-17 February), and early spring (18 February-15 March), Sheyenne National Grasslands, 1984-85.

	Vegetation Height Class			
	I	II	III	IV+
Roost Type	0-8 cm	9-25 cm	26-50 cm	≥50 cm
Vegetation				
Winter	0	8.8 (3)	76.5 (26)	14.7 (3)
Spring	2.1 (1)	29.2(14)	66.7 (32)	2.1 (1)
Vegetation and snow				
Winter	0	4.7 (5)	77.4 (82)	17.9(19)
Spring	0	0	100.0 (6)	
Snow Depression	.9 (9)	.9 (1)	79.1 (91)	19.1(22)
Unused Snow Depression	1.3 (1)	0	82.5 (66)	16.3(13)
Snow Burrow	2.3 (3)	.8 (1)	73.1 (95)	23.8(31)
Unsuccessful Snow Burrow	0	2.2 (1)	62.2 (28)	35.6(16)
Total winter	3.3(13)	2.6(10)	75.0(294)	19.1(75)
Total spring	3.9 (2)	13.7(17)	80.4 (41)	2.0 (1)
Random Points				
Winter	7.9(12)	23.7(36)	47.4 (72)	21.1(32)
Spring	32.3(32)	26.3(26)	37.4 (37)	4.0 (4)

It is believed that larger areas were selected for winter night roosting because of the greater security provided in the form of cover above the snow. In early spring there is more coverage available in a smaller area.
These roost areas were similar in type, height class and species composition to areas used by radioed prairie chicken hens for nesting. At least 9 of the areas used by prairie chickens for winter night roosting either were or had been used by radioed hens for nesting.

Thus the undisturbed lowland community on the SNG is the critical component for winter night roosting sites and nesting habitat for prairie chickens. These are the 2 places where an individual spends more than a few hours in one spot. The amount and distribution of this lowland cover on the SNG is determined by lowland mowing practices, the pattern of which will be a key factor in maintaining or improving habitat for prairie chickens on the SNG. Nesting and roosting cover along with winter food should serve as focal points for any future management plans for the prairie chickens on the Sheyenne National Grasslands.

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Diets of Greater Prairie Chickens on the Sheyenne National Grasslands[1,2]

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Abstract.-- Diets of greater prairie chickens on the Sheyenne National Grassland of North Dakota were examined. During the winter months agricultural crops (primarily corn) were the predominant food items. Green vegetation was consumed in greater quantities as spring progressed. Dandelion flowers and alfalfa/sweetclover were the major vegetative food items through the summer. Both juvenile and adults selected diets high in digestible protein obtained through consumption of arthropods and some plants.

INTRODUCTION

Initially, the development of agriculture on the prairies was credited with increasing the population and range of the greater prairie chicken (Tympanuchus cupido) (Hamerstrom et al. 1957). Further development however, of agriculture, primarily "clean farming", contributed to their decline (Yeatter 1963, Westemier 1980). Prairie chicken populations are highest in areas where agriculture is interspersed with grasslands in approximately a 1:2 ratio (Evans 1968). The quality of the grassland habitats is also important, however (Christisen and Krohn 1980).

Greater prairie chickens are primarily herbivorous, as are other grouse except during the juvenile stage (Evans 1968). Prairie chicken broods generally select areas of high herbaceous cover with forbs where they forage for insects. Winter is a critical period, during which prairie chickens depend on agricultural crops. Corn is generally thought to be the staple food of prairie chickens (Trippensee 1948, Hamerstrom et al. 1957) but other agricultural crops may be selected (Evans 1968).

The Sheyenne National Grassland is an island of suitable prairie chicken habitat in eastern North Dakota. Because the population of prairie chickens on the Sheyenne National Grassland increased during the period 1974-1980 (Manske and Barker 1981), the possibility of an annual harvest arose. Yet, the reasons for this population increase were not clear. As a result, this study was initiated by the Rocky Mountain Forest and Range Experiment Station, in cooperation with Montana State University to determine food habits of greater prairie chickens on the Sheyenne National Grassland.

This food habits study was designed to be part of a larger effort to gain a better understanding of the ecology of prairie chickens. Habitat selection patterns are reported elsewhere in this symposium.

METHODS

This study was conducted on the Sheyenne National Grassland, Custer National Forest, in southeast North Dakota. This area represents an island of tall- and mixed-grass prairie surrounded by farmland. Vegetative descriptions of seral stages and habitat types are provided by Manske and Barker (1981), and Barker and Manske (this proceedings).

Prairie chicken fecal samples were collected from marked night and day roost locations of radio marked birds, booming grounds, and incidental flushes. Eighty-seven percent of all samples were obtained from radio marked birds. Samples were collected between April and August of 1983-1984 (spring-summer samples) and December to February 1984-1985 (winter samples). Winter samples were collected only during periods when at least 3 cm of snow was present. Samples were air-dried and analyzed separately (Sparks and Malachek 1968) by the Diet Composition Laboratory at Colorado State University. Diet composition (percent dry weight) was estimated from one slide

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(containing 20 fields). Estimates of summer diets were based on 321 samples; winter diet were based on 119 samples.

Data from both periods were separately subjected to a divisive cluster analysis program (Ball and Hall 1967) to search for natural grouping of samples. There were few trends toward natural biological groupings such as sex, age, or monthly differences. Within the summer period however, brood samples tended to be different from adult samples. Therefore, data from adult diets are presented as monthly averages for winter and spring-summer; data from brood diets are presented separately.

The food item categories listed often represent combinations of similar food items. For example, corn includes small amounts of the corn plant (less than .02%); sunflower includes plant material and seeds from other species of the composit family and soybean includes other legume seeds which could not be discerned from soybeans. The food category forb seeds represents seeds from unidentified forbs. Other forbs, shrubs, and grass refers primarily to plant material other than seeds.

RESULTS

Winter Diets

A total of 34 different food items were found in winter samples. These were condensed into 9 categories (Table 1). Waste from agriculture crops comprised over 60% of diets during all winter months. Corn alone made up about 50% of the diets during each month, but sunflowers and soybeans made up over 50% of some individual samples. The frequency of occurrence of corn in prairie chicken diets was 83% compared to 39% for sunflower and 24% for soybeans. Grass seeds comprised a large portion of the December diets but were somewhat less important during January and February. Consumption of a variety of unidentified forb seeds was not apparent until January. During the latter two months of the winter, forb seeds were relatively important food items. Fringed sage (*Artemesia frigida*) in the prairie chicken diets increased from zero in December to 11% by February. A number of forbs of various species comprised about 9% of the diets during December, then declined during January followed by a slight increase in February. Shrubs were an unimportant food category during this study; Russian olive (*Elaeagnus angustifolia*) was taken most frequently. Vegetative material from grasses were also relatively unimportant. Kentucky bluegrass (*Poa pratensis*) was the predominant food item in this category.

Spring-Summer Diets

A total of 59 food items or categories were identified in the diets of adult prairie chickens between April and August. Of these only four were consistently important over the spring-summer period (Table 2). These four food categories over two-thirds of the prairie chicken diets.

During the prenesting through incubation period (April-May), dandelion (*Taraxacum officinale*) flowers, alfalfa/sweetclover and waste corn dominated the diets. Fringed sage continued to contribute a relatively constant portion of the diet from the winter months. During this period, corn declined while dandelion flowers and alfalfa/sweetclover increased . An unidentified composite comprised 13% of the diet in April but only about 2% in May.

Arthropods increased in importance as a food to adult prairie chickens in June and continued to increased throughout the summer. By August nearly 60% of the diet of adult prairie chickens was composed of arthropods. Consumption of dandelions declined in June and comprised about 10% of the diet throughout the summer. Alfalfa/sweetclover in prairie chickens diets increased throughout the spring to 42% in June, then declined to 15% by August.

Arthropods were the single most important food category of juvenile prairie chickens (Table 3),

Table 1. Percent composition of greater prairie chicken diets during winter (Dec.-Feb.) on the Sheyenne National Grasslands, North Dakota.

Species	December (N=7)	January (N=49)	February (N=63)
	$\bar{x} \pm$ se	$\bar{x} \pm$ se	$\bar{x} \pm$ se
Corn	49.3 ± 17.6	52.1 ± 5.9	50.8 ± 5.0
Sunflower	18.6 ± 12.6	3.0 ± 0.8	4.8 ± 1.3
Soybean	4.1 ± 2.7	6.3 ± 2.3	6.6 ± 2.7
Grass seeds	16.6 ± 9.2	7.7 ± 2.1	9.4 ± 2.1
Forb seeds	0	21.8 ± 4.4	8.5 ± 2.8
Artemesia frigida	0	4.0 ± 1.9	10.7 ± 2.7
Other forbs[1]	9.3 ± 3.5	2.9 ± 1.8	4.8 ± 1.4
Other shrubs[1]	0.2 ± 0.2	0.9 ± 0.3	2.7 ± 1.5
Other grasses[1]	1.8 ± 1.3	1.1 ± 0.5	1.6 ± 0.3

[1] Includes both identified and unidentified species.

Table 2. Percent composition of greater prairie chicken brood diets on the Sheyenne National Grasslands, North Dakota.

Species	June (N=15)	July (N=30)	August (N=30)
	$\bar{x} \pm$ se	$\bar{x} \pm$ se	$\bar{x} \pm$ se
Arthropod parts	80.1 ± 6.9	87.3 ± 3.5	86.3 ± 3.5
Taraxacum officinale	0	3.5 ± 2.4	1.5 ± 0.7
Medicago/melilotus spp.	7.4 ± 6.5	2.9 ± 1.4	4.5 ± 1.3
Artemesia frigida	0.1 ± 0.1	0.2 ± 0.1	0.1 ± 0.1
Flower parts	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
Unidentified composite	0	0.6 ± 0.4	1.8 ± 1.3
Poa pratensis	0.7 ± 0.4	0.6 ± 0.2	0.4 ± 0.2
Forb seeds	0	0.1 ± 0.1	0.2 ± 0.2
Carex spp.	5.6 ± 1.9	2.0 ± 0.5	0.3 ± 0.1
Grass seeds	0.3 ± 0.2	0.1 ± 0.1	0.1 ± 0.1
Equisetum spp.	0.6 ± 0.5	0.3 ± 0.1	0
Eleocharis spp.	3.3 ± 1.5	0.7 ± 0.5	0
Andropogon spp.	0	0.2 ± 0.1	0.1 ± 0.1
Ambrosia spp.	0	0.1 ± 0.1	0.2 ± 0.1
Agropyron spp.	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.1
Other forbs[1]	0.1 ± 0.1	0.3 ± 0.1	0
Other grasses[1]	1.3 ± 0.6	0.9 ± 0.2	0.7 ± 0.2
Other shrubs[1]	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.1

[1] Includes both identified and unidentified species.

Table 3. Percent composition of greater prairie chicken diets during spring-summer (April-August) on the Sheyenne National Grasslands, North Dakota.

Species	Month				
	April (N=45)	May (N=88)	June (N=39)	July (N=44)	August (N=27)
	$\bar{x} \pm$ se	$\bar{x} \pm$ se	$\bar{x} \pm$ se	$\bar{x} \pm$ se	$\bar{x} \pm$ se
Arthropod parts	8.0 ± 2.1	6.4 ± 1.2	26.3 ± 4.2	39.0 ± 5.3	59.8 ± 6.3
Taraxacum officinale flower	14.6 ± 4.6	26.5 ± 3.8	9.0 ± 3.5	10.7 ± 4.1	8.1 ± 3.8
Medicago/Melilotus spp.	20.6 ± 4.5	30.7 ± 3.8	42.7 ± 5.6	30.7 ± 5.4	14.8 ± 4.2
Corn kernel	22.5 ± 3.8	13.8 ± 2.1	1.9 ± 1.2	1.9 ± 1.9	2.8 ± 1.4
Artemesia frigida	7.9 ± 2.4	8.7 ± 2.2	0.9 ± 0.4	0.3 ± 0.3	0.3 ± 0.1
Flower parts	1.4 ± 1.1	1.6 ± 0.8	7.5 ± 2.7	3.5 ± 2.4	1.2 ± 0.1
Unidentified composite	13.4 ± 4.2	1.6 ± 0.8	2.3 ± 1.5	1.2 ± 0.5	5.9 ± 3.7
Antennaria/Cirsium spp.	1.3 ± 0.6	2.8 ± 1.5	0.2 ± 0.1	0.1 ± 0.1	0
Poa pratensis	1.1 ± 0.3	0.6 ± 0.2	0.2 ± 0.1	0.2 ± 0.1	0.4 ± 0.2
Forb seeds	2.1 ± 1.9	0.2 ± 0.1	1.9 ± 0.6	1.2 ± 0.5	0.2 ± 0.2
Carex spp.	0.3 ± 0.1	0.7 ± 0.3	0.7 ± 0.6	1.2 ± 0.4	2.8 ± 2.2
Rosa spp.	0.1 ± 0.1	0.4 ± 0.2	2.1 ± 2.1	0.3 ± 0.2	0.1 ± 0.1
Grass seeds	1.3 ± 0.7	0.2 ± 0.1	0.1 ± 0.1	0.2 ± 0.2	0.6 ± 0.4
Equisetum spp.	0.4 ± 0.3	0.3 ± 0.1	0	0.2 ± 0.1	0
Eleocharis spp.	0.3 ± 0.2	0.2 ± 0.1	0.3 ± 0.2	0.1 ± 0.1	0.1 ± 0.1
Andropogon spp.	0	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.4 ± 0.4
Ambrosia spp.	0.6 ± 0.4	0.5 ± 0.2	0.8 ± 0.7	2.5 ± 1.3	1.3 ± 0.9
Agropyron spp.	0	0.2 ± 0.1	0.1 ± 0.1	0	0
Other Forbs[1]	1.0 ± 0.4	0.9 ± 0.3	1.6 ± 0.7	1.4 ± 0.6	0.5 ± 0.3
Other Grasses[1]	0.6 ± 0.2	0.5 ± 0.2	0.2 ± 0.1	0.5 ± 0.2	0.7 ± 0.3
Other Shrubs[1]	0.1 ± 0.1	0.9 ± 0.9	0	0.1 ± 0.1	0.1 ± 0.1

[1] Includes identified and unidentified species.

comprising over 80% of the diet between June and August. Alfalfa/sweetclover was the only other food item consumed by juveniles in notable quantities throughout the summer. Prairie chicken chicks consumed some dandelion flowers later in the summer, and some shoots of sedges (Carex spp.) and rushes (Eleocharis spp.) during June. Other food categories recorded comprised less than 1% of the diets.

DISCUSSION

Waste corn was the most important single food item consumed during the winter months. Corn averaged of 90% of the diet in about 50% of the samples. However, for some individual birds, other food items were equally important. Both soybeans and sunflowers made up over 50% of some individual samples. Forb seeds were probably the next most important food category. High composition of forb seeds (over 30%) was found almost exclusively in samples from prairie chickens observed feeding in soybean fields the previous day. Soybean fields tend to contain many weeds due to the susceptibility of soybeans to herbicides. Forb seeds comprised over 50% (and up to 98%) of some individual samples. Prairie chickens on occasion were noted flying past corn fields on occasion to feed in soybean fields. Thus, most feeding during the winter by prairie chickens in this study was related to agriculture. Various agronomic crops were noted in prairie chicken diets in other regions (Korschgen 1962, Toney 1980, Horak 1985). However, selection of agronomic crops may reflect a preference rather than requirement at southern latitudes (Horak 1985).

Prairie chickens were first recorded in North Dalota in the 1880s following the spread of agriculture (Evans 1968). Whether prairie chickens were native to this region or not may be debated (eg. Kirsch and Kruse 1973), but prairie chicken numbers increased dramatically with the agricultural invasion on the prairie (Hamerstrom et al. 1957). It is our opinion that agriculture is now a necessary habitat component for prairie chickens in this area.

Prairie chickens often fed in fields during the mornings then moved to the edges of fields for day loafing. During December, grass seeds were probably consumed during day loafing while some grass seeds were still attached to stalks.

Of notable significance was the lack of "budding" by prairie chickens during the winter in this study. Prairie chickens used tree habitats on 5.5% of the observations but were observed budding only 1.1% of the time. The lack of shrub or tree buds in the diet may have been due to the lack of snow accumulation during a relatively mild winter. Thus, prairie chickens in this study were not forced to select shrubs as major food items.

Fringed sage appeared in the diets during January and increased in February. Fringed sage tends to retain green leaves during mild winters and may provide a source of green material as the birds get closer to the breeding season. Vitamin A, from green plant materials, was found to stimulate breeding in Gambel's quail (Callipepta gambelii) (Hungerford 1965). Fringed sage continued to make up about 10% of the diets through the prenesting and incubation periods.

During the prenesting and incubating periods, prairie chickens appeared to be selecting food items that were high in digestible energy and protein. Waste corn is obviously a high-energy food. The other dominant food items during this period were arthropods, which are high in protein, and dandelion flowers, alfalfa/sweetclover, and fringed sage. Forbs generally tend to be higher in digestible protein than grasses (Cook 1972). Increased protein intake during egg laying can result in less weight loss to laying hens (Beckerton and Middleton 1983). Hens loose 15-20% of their body weight during incubation and a hen's ability to successfully raise a brood may depend on her condition after incubation.

Dandelions were also the most important forb in gray partridge diets when available (Weigand 1980), and were highly selected for by sage grouse (Peterson 1970). Individual fecal samples contained up to 96% dandelion flowers during the spring (April-May), indicating that prairie chickens also appear to prefer dandelion flowers when available.

Waste corn was still being selected by the prairie chickens during early spring but consumption of corn declined as the breeding season progressed. Reduced consumption of corn corresponded to decreased use of agricultural habitats and increased use of grasslands, and coincided with spring greenup and field preparations for spring planting of new crops. Consumption of agricultural crops by prairie chickens in this study showed similar patterns to those in Missouri (Korschgen 1962, Toney 1980). During early spring, birds would typically visit display grounds during the morning and evening and feed in the fields during the day.

During the summer months adult prairie chickens continued to select for high-protein and high-energy food items. The level of protein in prairie chicken diets through consumption of arthropods increased from June through August, and probably reflected the increased availability of arthropods. Trends in the diets indicated that alfalfa/sweetclover were being traded for arthropods through the summer, which would indicate a trade off of plant protein for possibly more preferred animal protein. Insects were the dominant food item of lesser prairie chickens (T. pallidicintus) in Texas except during periods of low availability, during which acorns (Quercus harvardii) were selected (Doerr and Guthey 1983).

Prairie chicken hens attending broods occasionally selected diets similar in content to the juveniles. Some samples from hens attending broods contained over 80% arthropods. However, high quantities of arthropods were not being selected consistently by hens with broods. The reasons for the occasional selection of high quantities of arthropods by hens are unclear, the data did not result from misidentified brood samples, however. Brood samples were easily identified from adult samples on the basis of size.

The high composition of arthropods in the diets of juveniles was expected. The diets of most young gallinaceous birds are dominated by arthropods during their first 8-12 weeks (Kobridger 1965, Petersen 1970, Doerr and Guthery 1983, Whitmore et al. 1986). The importance of arthropods in the diets of young birds has been related to protein demands of the growing young (Cross 1966, Potts 1980, Hurst and Poe 1985). Experiments with sage grouse (Centrocercus urophasianus) chicks fed diets of varying amounts of insects showed that developmental deficiencies were apparent for birds whose diets contained restricted amounts of insects (Johnson 1987). Despite the importance of insects in diets, habitat selection patterns in sharp-tailed grouse in Nebrasks were not determined by the abundance of insects, however (Kobridger 1965).

Juvenile prairie chickens consumed small amounts of some vegetation throughout the summer. Sedges and rushes were found in the diets in notable quantities only when these plants were producing new shoots. Whether the sedges and rushes selected were from mesic or xeric species was not known; broods used habitats where both occurred (Newell 1987). Sedges and rushes declined in the diets following periods of initial rapid growth. Alfalfa/sweet clover was consumed by juvenile prairie chickens throughout the summer in low quantities. We suspect that these amounts of may have been related to availability of arthropods and succulence of the vegetation. Alfalfa produces new growth throughout the summer following cutting of fields for hay, and appeared in the diets throughout the summer. Alfalfa/sweetclover also tend to be higher than other forbs and grasses in digestible protein and energy (Church 1972, White and Wright 1984). Clover (Trifolium spp.), also a leguminous forb, was the most important plant food item for immature sharp-tailed grouse in Nebraska (Kobridger 1965). All of these plant foods items decreased in the diets as arthropods increased through the summer.

Low amounts of the several other species of vegetation which appeared in the diets of both adults and juveniles may have been from incidental intake from the guts of herbivorous arthropods (Hansen 1975).

CONCLUSIONS AND IMPLICATIONS

Agricultural crops interspersed with grassland habitats provide an important source of winter food for prairie chickens in this area. The importance of these high energy foods to sustaining prairie chicken populations may increase in regions with cold temperatures and snow accumulations. Although prairie chickens fed in both soybean and sunflower fields, corn appeared to be the most important single food item during the winter. Establishment of corn food plots could be a viable management objective if winter food were determined to be limiting this population of prairie chickens.

Agricultural crops declined in importance with a corresponding increase in consumption of green vegetative materials and arthropods during the spring. This diet shift coincided with breeding activities and spring field preparation. Forbs and arthropods were the dominant food items through the summer. These food items indicated that adult prairie chickens were selecting for food high in digestibility and protein. Prairie chicken chicks consumed diets high in animal protein as expected, but included some plants through August.

Whereas there are few management alternatives for enhancing food availability on the grasslands during the spring-summer, other management actions could be detrimental. Pest management that impacts nontarget insects could have detrimental impacts on brood survival and growth due to the dependence of the juvenile prairie chickens on arthropods. Direct manipulation of vegetation to enhance native clover or dandelions is not recommended. However, inclusion of leguminous forbs in rangeland seeding mixes is recommended.

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Management of Livestock to Improve and Maintain Prairie Chicken Habitat on the Sheyenne National Grasslands[1,2]

Robert L. Eng, John E. Toepfer, and Jay A. Newell[3]

Abstract-- Cover requirements of prairie grouse are primarily related to vegetative structure, whereas food needs are species related. Seasonal distribution and intensity of grazing initially alter the structure and ultimately can alter species composition. Initial successful nests were found in areas of more and higher residual cover than unsuccessful nests. Nesting areas were similar in type and height class to areas used by prairie chickens for winter and spring roosting. Success of renesting hens was higher than initial nests which was probably a function of additional cover provided by current year's growth. A key factor influencing prairie grouse numbers lies in the amount and distribution of residual grass cover (15-50 cm, ht) within 1.6 km of a display ground. On the Sheyenne Grasslands, this cover was almost entirely found in the lowlands and midlands. Grazing and haying management of these two communities will have the greatest impact on prairie chickens.

One need only look at published reports of cover requirements for a widely distributed gallinaceous species to see that the common denominator for secure cover lies in structure rather than plant species composition. Hammerstrom et al. (1957) discussed this aspect of cover for prairie chickens in Wisconsin. Jones (1963), in comparing habitats of the greater and lesser prairie chicken (Tympanuchus cupido and T. pallidicinctus), generally found the greater using tall grasses for cover, while the lesser in shortgrass habitat used shrubs. Likewise, Nielsen and Yde (1981) found sharptails (Tympanuchus phasianellus) using shrubs for cover in the absence of grass of adequate height. Perhaps an extreme in seeking the structural cover requirements, was the heavy use of man-made objects (largely farm machinery) by scaled quail (Calipepla squamata) reported by Schemnitz (1961). In this symposium, Newell et.al. reported on the heavy dependence by prairie chickens on cover height during the reproductive season as did Toepfer and Eng for the winter season. This paper summarizes some of these data and relates them to livestock management on the Sheyenne National Grasslands (SNG).

Reproductive Season

Seventy-six prairie grouse nests were located, just under 80% of which were located on USFS grasslands (Newell 1987). Only 9% were found on private grasslands and of these 7 nests, only 1 was successful. Just over 80% of the nests located on public lands were located in lowlands (56%) and midlands (25%), while only 3% were located in the most heavily grazed uplands. Structural cover was measurably greater at successful nests than at unsuccessful nests (Newell 1987).

Renesting attempts were more successful (68%) than initial efforts (48%), probably a reflection of the greater amount of cover as a result of current seasons growth. Nesting cover for first nests was invariably provided by residual grasses and sedges, the quality of which was dependent upon the degree of disturbance the previous year. Leopold (1933: 309)) pointed out that waterfowl and gallinaceous birds tend to intitiate nesting efforts prior to new green growth. A decided tendency was shown for nesting chickens to avoid pastures in which cattle were present when 11 of 13 renesting hens which had an option, selected pastures without cattle. The 2 which nested in pastures being grazed, selected the site prior to cattle being moved in.

Hens with and without broods showed a preference for native stands of vegetation over agriculture and made extensive use of lowland habitats. Also, brood and broodless hens tended to seek areas which had little or no disturbance

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[2]Contribution No. 2145 from Montana Agric. Exp. Stn.
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(grazing or mowing) during the current year. Roosts by hens during the brood season were primarily found in Class III (26-50 cm) or taller vegetation.

Winter Season

Although prairie chickens on the SNG spent considerable time in disturbed types during the winter while feeding, undisturbed grassland played a key role in their habitat use, with 78% of observed roosts in this type of habitat. From a structural standpoint, 94 % of all roost types were in association with Class III or taller vegetation. Height Classes I and II (0-25 cm) which include areas disturbed by agriculture or grazing, were used primarily during the day for feeding (Figs. 1 and 2). Conversely, the undisturbed lowland community found on the SNG provided the taller Class III and IV (26+ cm) cover used extensively for night roosting (Figs. 3 and 4).

Taller height classes of vegetation played a dual role in providing cover for winter roosting prairie chickens. Birds used the vegetation itself in the absence of snow of adequate depth for burrowing. Taller vegetation also acted to accumulate drifting snow providing sufficient depths for snow burrows or depressions (Fig. 5). At no time during the winter of study, did snow accumulate on the level to a minimum depth required for snow burrowing (23+ cm).

Grazing Management Recommendations

The importance of the lowland and midland communities to prairie chickens on the SNG cannot be denied. These two communities recieved most of the winter and spring use by all hens and in summer by brood hens. None of the nests were located in an upland grass community or in a mowed lowland. Renests were more successful than initial nests, indicating a deficit in residual cover prior to current years growth. Thus, modifications in the management of the lowland and midland communities could have the greatest positive impact on prairie chickens.

Mowing of lowland vegetation was carried out primarily to remove rank vegetation and encourage cattle to graze on these areas thereby reducing pressure on the uplands. Mowing was done on a block basis with all the lowlands in a single pasture removed. A major benefit to prairie chickens could be derived from an adjustment in the mowing pattern to provide a wider distribution of unmowed lowlands. Secondly, efforts should be made to increase the total amount of undisturbed lowland and midland for nesting and winter roosting. One possibility to insure both a more even distribution and an increase acreage of residual grasses would be to mow one third of each pasture in a 3-pasture allotment on a three year rotational basis. A second alternative would be to evaluate individural allotments relative to grouse numbers. Using bird numbers as a habitat index, mowing and grazing practices would remain the same within a 1.6 km radius of booming grounds with high numbers of birds while adjustments could be made around booming grounds with low or unstable numbers. The latter alternative would necessitate a reliable monitoring of population numbers and distribution.

Adjustments in the timing of mowing could be advantageous. By delaying mowing of lowlands until 10 August, most nesting activities would be complete and broods mature enough to avoid mowers. Renesting activities were quite significant toward production in this study, with 6 radio-tagged hens bringing off broods after 10 July. Field observations have shown that chicks less than 21 days old sit rather than fly when threatened. A delayed mowing date would make these chicks less vulnerable.

Adjustments in turn-in dates for cattle provides another alternative for a positive impact on prairie chickens. Delaying the introduction of cattle into pastures until June 1 or 15, or distributing the cattle evenly between pastures for the first 2 weeks, would increase the amount of early vegetational cover for early hatching broods.

Recommendations thus far have dealt almost entirely with vegetation structure. Although sharptails used habitat types, height classes and disturbance types on the SNG in a manner comparable to prairie chickens, they used the shrub habitat at a rate 3 times greater. It appears that sharptails are the more aggressive of the 2 species. In this study, while sharing feeding areas, sharptails dominated prairie chickens in 87 of 94 aggression encounters. In 5 of 6 locations in 3 states that we are aware of where both species inhabited the same area, only sharptails remain. Thus, changes in the distribution and relative abundance of shrub species on the SNG could influence the current balance between the two grouse species. Spring inventory should be maintained at a level sufficient to detect changes in the composition and distribution of the two grouse species and shrub control could be implemented if needed and desired to favor prairie chickens.

Although winter food from agricultural crop is usually available, deep and/or crusted snow can eliminate this food source. Recorded shifts in daily ranges clearly indicates the instability of winter food sources, a condition which at times could contribute to reduced survival and production. A more dependable food source could be provided in the form of standing corn or sunflowers, strategically located with respect to known wintering areas booming grounds.

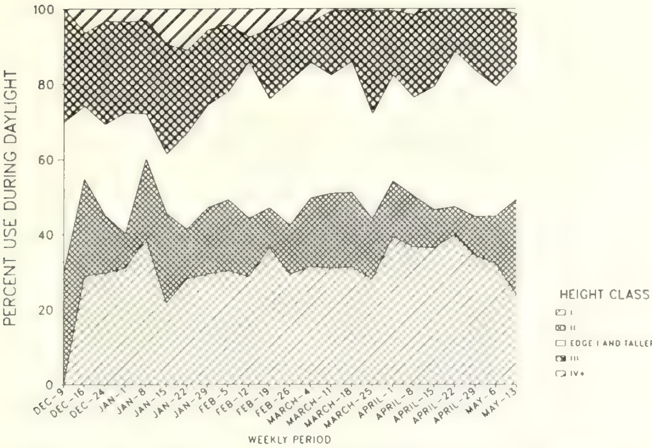

Fig. 1. Weekly use of vegetation height classes (I=0-8 cm, II=9-25 cm, III=26-50 cm, IV=50+ cm) during the daytime by radio-tagged prairie chickens, on the SNG, 1984-85.

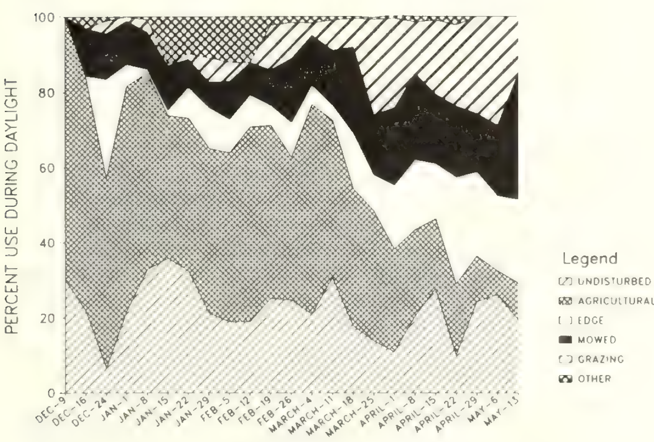

Fig. 2. Weekly use of disturbance types during the daytime for radio-tagged prairie chickens, SNG, 1984-85.

Fig. 5. The accumulation of snow by vegetation, SNG 1984-85.

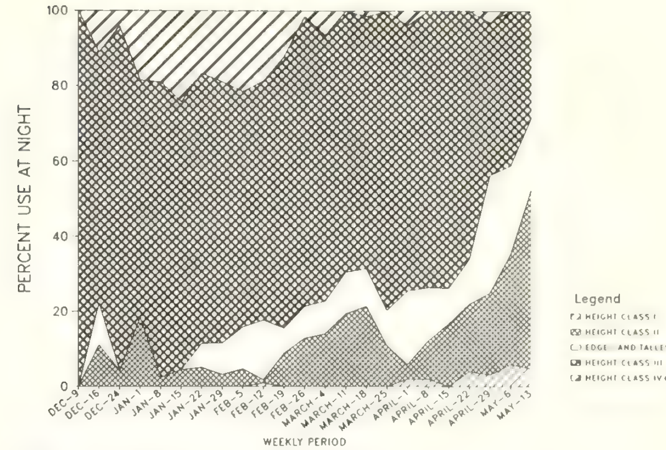

Fig. 3. Weekly use of disturbance types at night for radio-tagged prairie chickens, SNG, 1984-85.

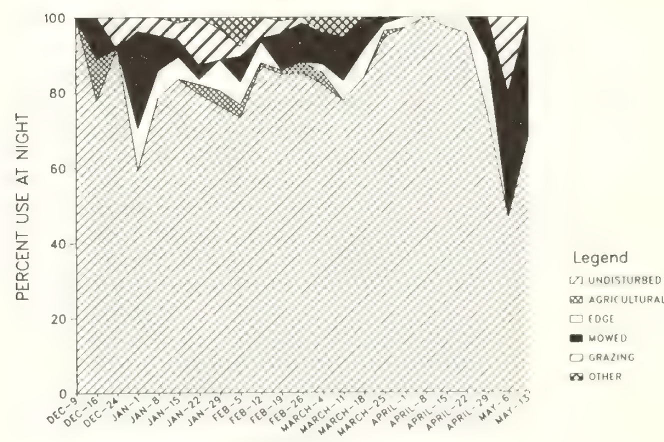

Fig. 4. Weekly use of vegetation height classes (I=0-8 cm, II=9-25 cm, III=26-50 cm, IV=50+ cm) at night by radio-tagged prairie chickens on the SNG, 1984-KD85.

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Effects of Grazing Management Treatment on Grassland Plant Communities and Prairie Grouse Habitat[1]

Llewellyn L. Manske, William T. Barker, and Mario E. Biondini[2]

Abstract.--Seasonlong grazing treatments show no benefit to grass basal cover and visual obstruction is not adequate. Pastures with one grazing period in mid season show no positive change in grass basal cover but have better visual obstruction than seasonlong. Deferred grazing decreases basal cover of warm season grasses and visual obstruction reduced to inadequate levels the first growing season after treatment. Pastures with two grazing periods show increase in basal cover and have adequate visual obstruction. Prairie grouse select against use in seasonlong, one period mid season and deferred grazing treatments but select for pastures grazed two periods for display ground and nest locations.

The effects of grazing by domestic livestock on grassland plant communities depend on season of use, intensity of grazing and duration of grazed and ungrazed periods. Differential responses of the vegetation to grazing management treatments affects the prairie grouse populations that depend on grassland plants for habitat. The different affects on the plant communities and prairie grouse habitat by the various types of grazing management treatments were not well understood. The purpose of this project was to determine the effects of selected grazing management treatments on the grassland plant communities and prairie grouse habitat and evaluate prairie grouse use of the different grazing treatments.

STUDY AREA

This study was conducted on the Sheyenne National Grasslands located in southeastern North Dakota in Ransom and Richland Counties on a geologic formation known as the Glacial Sheyenne Delta. The north unit consists of 67,320 acres of federal land and 63,240 acres of private land. Average annual precipitation was 19.6 inches with 79% of this occurring April through September (Jensen 1972). The frost-free period averages 130 days beginning in mid May. Mean monthly temperatures were highest in July and August (70.9° and 69.9°F, respectively) and lowest in January (7.7°F) (Jensen 1972). The vegetation consists of native grassland and woodland and non-native replacement communities (cropland). These were described by Manske and Barker (1981).

The federally owned land on the Sheyenne National Grasslands was purchased as submarginal farm land from private ownership from 1937 to 1939 after the Congress passed the Bankhead-Jones Farm Tenant Act. The administration of these lands was assigned to the Soil Conservation Service in 1940. The federal land was divided into 10 common grazing blocks which were grazed seasonlong. The grazing season was 8 months from 1940 to 1954. In 1954, the administration was transferred to the U.S. Forest Service. The grazing season was changed to 6 months in 1955 and the common grazing blocks were divided into 56 grazing allotments. These allotments were managed by a seasonlong grazing system. Cross fencing of the allotments began in 1967. Twenty-two allotments were managed by rotation grazing systems with one grazing period per pasture in 1968. In 1974, rotational grazing systems were used on 63% of the allotments (84% of the federal land). Twice over rotation systems (two grazing periods per pasture) were started by District Ranger Robert Storch in eleven allotments in 1974 upon the recommendation of Dr. William T. Barker. The number of allotments that had pastures with twice over rotation grazing periods increased

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until 1978 when 54% of the federal land was managed with twice over systems. In 1979, this management trend was reversed with a change in District Rangers and 70% of the federal land was managed with once over and deferred grazing systems and only 20% with twice over rotation systems. Less than 10% of the federal land was managed with a seasonlong grazing system in 1980. Most of the allotments were grazed by one herd managed as a unit.

METHODS

Records from the Sheyenne Valley Grazing Association of grazing management plans for each grazing allotment from 1974 through 1980 were reviewed and each allotment was classified to type of grazing management treatment for each year. The types of management were categorized by the number of pastures in each system, the number of grazing periods for the pasture with the least number of periods and the season when the grazing periods occurred. The grazing treatments consisted of 1, 2, 3 and 4 pastures. The number of grazing periods varied from 1 to 4 periods. Two 5 pasture systems were designed but these were primarily managed as 2 and 3 pasture systems with 2 herds where some exchange of herds between systems occurred.

The one pasture treatments were grazed one period seasonlong for 183 days. Examples of this type were used as the control treatment. The two pasture systems had examples of 1, 2, 3 and 4 grazing periods. Each pasture was grazed for a total of about 90 days. Only the pastures with 3 and 4 grazing periods (switchback system) were included in this study.

The three pasture treatments were primarily grazed 1, 2 or 3 periods (once, twice or thrice over systems, respectively). Most 3 pasture systems had two pastures grazed twice over and the third pasture grazed once over. The pasture with one grazing period was grazed during the mid season period of June to early September or they were deferred until after grass seed development in late August and grazed only during the late season period of September to mid November. These deferred pastures were not grazed from August of the previous year until late August or September of the year of deferment. These pastures were ungrazed for 11 to 13 months prior to the deferred grazing period. This one year period of ungrazing was included in this study as a treatment. The pastures with two grazing periods were grazed during three season of use categories; early season (May - mid June), mid season (June - early September) or late season (September - mid November). Two grazing periods in three season of use categories resulted in four possible combinations; early - late, early - mid, mid - mid and mid - late. Each pasture was grazed for a total of about 60 days.

Four pasture grazing management treatments were used in 6 allotments which was about 20% of the federal land. These were generally managed as 3 pasture systems with the fourth pasture used for herd splitting for breeding or other purposes or to maintain separation between old cows and heifers. None of these 4 pasture treatments were true one herd 4 pasture rotation systems and were not evaluated as such in this study.

Basal cover was determined in August, 1976 - 1978, by sampling along permanent transect segments on identical slope position in the upland, midland and lowland plant communities with the inclined ten-pin point frame (Levy and Madden 1933, Tinney, Aamodt and Ahlgren 1937, Heady and Rader 1958, and Smith 1959). Fifteen hundred points were read for each plant community per sample stand. Relative changes in basal cover between pretreatment and post treatment were estimated in each pasture for both grazed and ungrazed paired plots. The effects of the different grazing treatments on these relative changes were analyzed with a standard paired plot t test (Mosteller and Rourke 1973).

Visual obstruction was sampled by the height-density method developed by Robel et al. (1970a), and modified by Kirsch (1974). The ability of the grassland vegetation to obstruct vision was considered to be a very important factor in the evaluation of prairie grouse habitat (Hamerstrom et al. 1957, and Robel et al. 1970b). Mean 100% visual obstruction measurements of 1.5 decimeters was considered to be the minimum level for good nesting success and roost cover for prairie grouse Manske and Barker (1981) and Higgins and Barker (1982). The Panicum virgatum (switchgrass) portion of the midland grassland community located on the foot slope was the primary prairie grouse concealment cover on the Sheyenne National Grasslands (Manske and Barker 1981). This switchgrass area was selected as the key vegetation to evaluate the effects of different grazing treatments on prairie grouse habitat. Readings to the nearest 0.5 decimeters (2 inches) were made for the 0% and 100% visual obstruction measurements (VOM) of the height-density pole at four major compass directions. Twenty-five pole sets with an interval of 12 paces were made in homogenous vegetation along a transect of about 270 meters (900 feet). Permanent transects were established in 17 pastures with 5 different grazing treatments. These permanent transects were read spring and fall of 1979 and 1980. Nonpermanent transects were sampled during the spring of 1979 or 1980 in 40 pastures with 8 grazing treatments. Fall data from nonpermanent transects collected on deferred pastures prior to the grazing period were also included. The data collected on the permanent and non-permanent transects were treated separately and analysed using an unbalanced AOV (Mosteller and Rourke 1973).

Location of spring display grounds (Manske and Barker 1981) were classified according to the type of grazing treatment the pasture received the previous year. Use index (% of display location/% of study area) as described by Robel et al. (1970b) was used to evaluate display ground-management interactions. An index value greater than 1.0 indicates selection for that grazing treatment, a value less than 1.0 indicates use less than would be expected if the grouse exhibited no preference. A value of zero indicates avoidance of that treatment category.

Prairie chicken and sharp-tailed grouse nest locations (Manske and Barker 1981) were classified according to the type of grazing treatment the pasture received the previous year. Statistical analysis was not done on the nest location data.

RESULTS AND DISCUSSION

Seasonlong grazing treatments were used on the Sheyenne National Grasslands from 1940 through 1967. The prairie grouse population was very low (less than 25 males) during this period and did not show any increase. In 1968, rotation grazing treatments were started. By 1973, 75% of the federal land was managed by some type of multiple pasture rotation system with one grazing period per pasture. Eighteen pastures in 15 allotments had two grazing periods in 1971. Prior to this, pastures were grazed for one period. There was a large increase in prairie grouse population between 1971 and 1972. During the period of 1968 to 1974 the population of prairie chicken and sharptailed grouse increased appreciably. Management with two grazing periods on multiple pastures within an allotment started in 1974. There was a very large increase in the prairie grouse population in the spring census of 1975. Management with twice over grazing periods increased from 10% of the federal land in 1974 to 54% in 1978. The prairie grouse population increased substantially during this 5 year period. The increasing trend for management with multiple grazing periods on pastures was changed to single grazing periods and deferred type grazing management in 1979. Seventy and seventy-one percent of the federal land was managed by treatments with single grazing periods in mid season or deferred until late season in 1979 and 1980, respectively. The prairie grouse population responded negatively to these changes in management and greatly declined in the spring census of 1981.

Acreages and percentages of federal land managed with 1, 2, 3, and 4 pasture treatments from 1974 through 1980 are shown in table 1. Mean annual acreage for 1, 2, 3 and 4 pasture treatments was 7,369 (11.0%), 11,518 (17.2%), 34,759 (52.0%) and 13,224 (19.8%) acres, respectively. Mean stocking rate of all allotments was 0.88 AUM's/acre. Mean stocking rate for one, two, three (once over) and three (twice over) pasture treatments were 0.75, 1.08, 1.17, 1.07 AUM's/acre, respectively (Table 2). The one pasture seasonlong treatments were stocked below ($P<0.05$) the two and three pasture treatments. The stocking rates for the two pasture, switchback; three pasture, once over; and three pasture, twice over treatments were not significantly different ($P>0.05$).

Basal cover data of individual species were grouped as warm season, cool season and sedges (Tables 3, 4 and 5, respectively). The major species of each plant community were evaluated individually. Data for Panicum virgatum (switchgrass) and Poa pratensis (Kentucky bluegrass) were reported in Table 6.

Basal cover of the warm season grasses (Fig. 1) was significantly reduced by the deferred grazing treatment (#4) in the midland plant community ($P<0.05$). Warm season basal cover (Fig. 1) was reduced ($P<0.05$) in the lowland plant community of the two pasture, thrice over grazing treatment (#2). Changes in basal cover for the warm season grasses in the upland plant communities for the ten treatments were not significant ($P>0.05$). Basal cover of the warm season grasses on the lowland community decreased significantly ($P<0.05$) on the two pasture, thrice over treatment (#2) compared to the seasonlong treatment (#1).

Basal cover for the cool season grasses (Fig. 2) did not change significantly ($P>0.05$) in the upland, midland and lowland plant communities for the ten grazing treatments.

Basal cover for the sedges (Fig. 3) in the lowland community were significantly ($P<0.1$) increased on the three pasture, twice over grazed early and late season treatment (#7). Sedges did not change ($P>0.05$) in the upland and midland communities for the ten grazing treatments. Basal cover of the sedges on the lowland community increased significantly ($P<0.05$) on the three pasture, twice over grazed early and late season treatment (#7) compared to the seasonlong treatment (#1).

Basal cover for Panicum virgatum (Fig. 4) was significantly reduced in the midland ($P<0.05$) and lowland ($P<0.1$) plant communities of the deferred grazing treatment (#4). The three pasture, twice over, grazed early and late treatment (#7) reduced the basal cover of Panicum virgatum (Fig. 4) in the lowland plant community ($P<0.05$). The two pasture thrice over treatment (#2) reduced the basal cover of Panicum virgatum ($P<0.05$) and increased the basal cover of Poa pratensis ($P<0.05$) in the lowland plant community (Fig. 4). Basal cover of Panicum virgatum in the midland community decreased significantly ($P<0.05$) on the three pasture, once over deferred treatment (#4) compared to the seasonlong treatment (#1). Panicum virgatum

Table 1. Annual acreage and percentage of federal land managed with 1, 2, 3 and 4 pasture treatments.

Treatment		Year						
		1974	1975	1976	1977	1978	1979	1980
One Pasture								
Seasonlong	acres	10,977	6,867	6,867	6,926	6,926	6,566	6,457
	%	16.4	10.3	10.3	10.4	10.4	9.8	9.7
Two Pasture								
Once Over,								
Mid Season	acres	4,658	6,595	5,273	3,404	3,404	5,766	6,450
	%	7.0	9.9	7.9	5.1	5.1	8.6	9.7
Switchback	acres	4,466	4,147	5,469	9,336	9,336	6,974	5,348
	%	6.7	6.2	8.2	14.0	14.0	10.4	8.0
Three Pasture								
Deferred,								
Late Season	acres	4,384	11,021	5,572	3,072	3,512	21,360	17,041
	%	6.6	16.5	8.3	4.6	5.3	31.9	25.5
Once Over,								
Mid Season	acres	26,698	18,679	18,569	13,416	11,887	7,133	12,557
	%	39.9	27.9	27.8	20.1	17.8	10.7	18.8
Twice Over,								
Early, Mid, Late	acres	2,248	5,596	12,623	18,219	19,308	5,236	5,182
	%	3.4	8.4	18.9	27.3	28.9	7.8	7.8
Four Pasture								
Deferred,								
Late Season	acres	0	0	0	0	0	2,572	3,456
	%	-	-	-	-	-	3.9	5.2
Once Over,								
Mid Season	acres	13,439	12,720	11,252	5,090	5,090	10,018	7,900
	%	20.1	19.0	16.8	7.6	7.6	15.0	11.8
Twice Over,								
Early, Mid, Late	acres	0	1,245	1,245	7,407	7,407	1,245	2,479
	%	-	1.9	1.9	11.1	11.1	1.9	3.7

Table 2. Total number of days grazed per pasture and stocking rate for 1, 2 and 3 pasture grazing treatments. Means of same column followed by the same letter are not significantly different ($P<0.05$).

	Total number days grazed	Stocking rate AUM/acre
1 Pasture, Control		
Seasonlong	183.7 ± 0.5	0.75 ± 0.01a
2 Pasture, Switchback		
3 Grazing Periods	87.3 ± 4.5	1.08 ± 0.01b
4 Grazing Periods	92.5 ± 4.3	1.08 ± 0.01b
3 Pasture, Once Over		
Deferred, Late	58.2 ± 5.3	1.15 ± 0.09b
Ungrazed	11-13 months (Sep-Sep)	1.17 ± 0.09b
Mid Season	60.3 ± 6.7	1.18 ± 0.0b
3 Pasture, Twice Over		
Early - Late	59.7 ± 0.5	1.10 ± 0.06b
Early - Mid	57.9 ± 2.8	1.10 ± 0.10b
Mid - Mid	59.7 ± 2.6	1.04 ± 0.04b
Mid - Late	59.8 ± 3.2	1.03 ± 0.03b

Table 3. Basal cover of warm season grasses pretreatment and post treatment for ten grazing treatments.

			Upland		Midland		Lowland	
Treatment	Treatment number	Grazing status	Pre treatment	Post treatment	Pre treatment	Post treatment	Pre treatment	Post treatment
One Pasture, Control								
Seasonlong	1	Grazed	20.1	14.8	11.3	9.1	0.3	0.4
n = 2		Ungrazed	30.2	28.3	16.0	16.0	0.3	0.3
Two Pasture, Switchback								
3 Grazing Periods	2	Grazed	26.7	22.5	17.6	14.3	1.5	0.2
n = 2		Ungrazed	32.8	27.7	20.7	15.6	0.1	0.6
4 Grazing Periods	3	Grazed	28.5	20.7	19.7	13.7	0.5	1.6
n = 2		Ungrazed	28.0	23.5	25.1	14.7	0.8	0.6
Three Pasture, Once Over								
Deferred	4	Grazed	9.6	11.2	18.9	14.0	4.0	9.4
n = 4		Ungrazed	25.4	13.7	12.4	20.0	2.1	7.2
Ungrazed	5	Grazed	11.8	0.4	31.9	21.1	10.9	7.7
n = 3		Ungrazed	14.8	2.4	25.5	18.4	4.7	4.3
Mid Season	6	Grazed	29.2	39.6	13.8	18.6	1.0	9.4
n = 1		Ungrazed	29.8	38.0	17.8	20.0	1.4	5.6
Three Pasture, Twice Over								
Early - Late	7	Grazed	27.6	31.9	17.5	24.3	2.8	4.8
n = 3		Ungrazed	24.9	28.5	19.9	23.1	1.3	5.8
Early - Mid	8	Grazed	35.5	25.0	27.1	22.3	7.9	6.3
n = 6		Ungrazed	35.8	20.6	31.9	22.2	6.1	3.0
Mid - Mid	9	Grazed	24.6	23.7	16.2	16.6	3.0	4.8
n = 5		Ungrazed	22.7	18.9	20.8	18.5	1.8	2.6
Mid - Late	10	Grazed	20.5	17.8	28.1	16.5	3.8	3.5
n = 5		Ungrazed	21.2	17.2	29.4	18.4	4.8	2.9

Table 4. Basal cover of cool season grasses pretreatment and post treatment for ten grazing treatments.

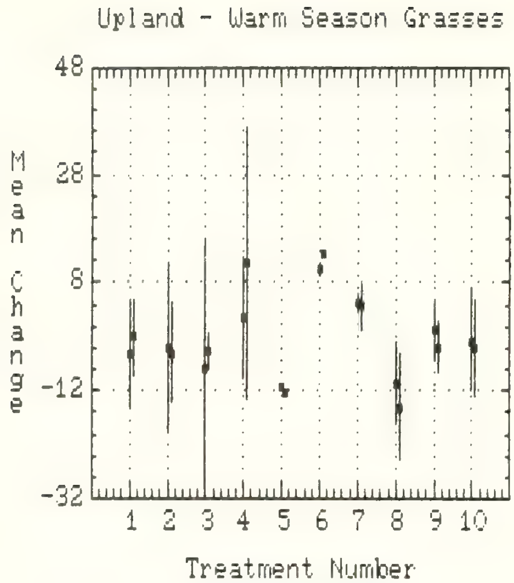
			Upland		Midland		Lowland	
Treatment	Treatment number	Grazing status	Pre treatment	Post treatment	Pre treatment	Post treatment	Pre treatment	Post treatment
One Pasture, Control								
Seasonlong	1	Grazed	13.3	11.9	18.1	13.3	4.1	9.4
n = 2		Ungrazed	15.2	5.4	13.5	9.9	6.2	10.7
Two Pasture, Switchback								
3 Grazing Periods	2	Grazed	14.9	5.8	15.4	13.7	1.9	6.6
n = 2		Ungrazed	10.0	4.5	18.0	11.2	1.6	5.8
4 Grazing Periods	3	Grazed	7.6	6.5	16.7	11.9	4.2	8.0
n = 2		Ungrazed	8.9	7.0	15.5	12.1	1.5	7.3
Three Pasture, Once Over								
Deferred	4	Grazed	18.7	11.9	17.1	13.2	3.5	11.9
n = 4		Ungrazed	9.5	7.7	17.0	12.7	5.4	12.2
Ungrazed	5	Grazed	34.2	10.2	11.1	8.3	6.2	9.1
n = 3		Ungrazed	32.4	9.6	15.1	9.3	6.3	11.1
Mid Season	6	Grazed	3.0	7.2	6.6	15.2	10.2	21.6
n = 1		Ungrazed	8.2	8.2	7.8	17.6	6.4	10.6
Three Pasture, Twice Over								
Early - Late	7	Grazed	2.7	4.9	8.0	8.9	6.9	14.3
n = 3		Ungrazed	3.3	6.7	9.7	11.2	3.7	10.3
Early - Mid	8	Grazed	17.7	2.8	15.9	7.6	7.1	9.7
n = 6		Ungrazed	15.1	4.5	11.8	8.4	6.6	7.4
Mid - Mid	9	Grazed	7.7	8.7	14.8	14.6	10.1	15.6
n = 5		Ungrazed	9.9	11.2	11.2	14.9	7.2	15.2
Mid - Late	10	Grazed	19.6	9.8	15.4	15.7	11.2	13.2
n = 5		Ungrazed	22.0	11.6	15.6	11.9	11.7	14.8

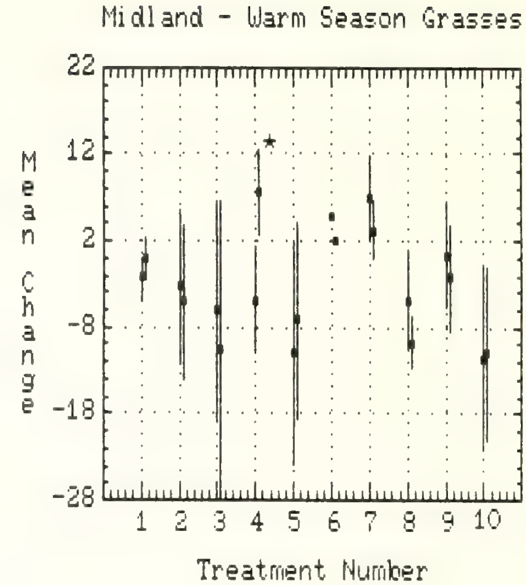
Table 5. Basal cover of sedges pretreatment and post treatment for ten grazing treatments.

Treatment	Treatment number	Grazing status	Upland Pre treatment	Upland Post treatment	Midland Pre treatment	Midland Post treatment	Lowland Pre treatment	Lowland Post treatment
One Pasture, Control								
Seasonlong	1	Grazed	8.4	3.6	14.7	6.1	24.0	18.1
n = 2		Ungrazed	3.6	3.6	14.4	6.8	25.6	20.7
Two Pasture, Switchback								
3 Grazing Periods	2	Grazed	6.2	4.6	20.4	7.2	35.7	16.2
n = 2		Ungrazed	6.8	3.3	15.1	7.0	27.5	14.4
4 Grazing Periods	3	Grazed	7.1	4.4	17.3	7.8	23.3	16.1
n = 2		Ungrazed	7.3	4.6	15.2	7.6	22.7	20.0
Three Pasture, Once Over								
Deferred	4	Grazed	12.6	6.9	10.7	5.6	23.0	12.9
n = 4		Ungrazed	11.3	8.4	13.2	8.3	23.9	14.2
Ungrazed	5	Grazed	5.2	6.4	10.0	5.1	24.7	10.8
n = 3		Ungrazed	20.8	8.0	12.1	6.7	24.9	12.6
Mid Season	6	Grazed	1.6	2.0	5.0	9.6	13.8	13.2
n = 1		Ungrazed	1.0	1.2	3.0	10.8	19.0	25.4
Three Pasture, Twice Over								
Early - Late	7	Grazed	2.8	3.4	4.9	5.1	10.8	17.1
n = 3		Ungrazed	3.5	3.7	6.3	6.5	14.3	17.5
Early - Mid	8	Grazed	5.4	3.7	11.6	4.4	27.7	12.7
n = 6		Ungrazed	3.8	3.4	8.6	6.1	28.4	16.6
Mid - Mid	9	Grazed	2.8	3.5	6.6	5.5	15.1	15.1
n = 5		Ungrazed	4.5	5.6	5.1	4.6	16.0	13.2
Mid - Late	10	Grazed	5.5	3.3	6.1	5.3	23.4	13.4
n = 5		Ungrazed	8.8	4.3	6.4	4.8	19.2	13.6

Table 6. Basal cover of Panicum virgatum and Poa pratensis pretreatment and post treatment for ten grazing treatments.

Treatment	Treatment number	Grazing status	Panicum virgatum Midland Pre treatment	Panicum virgatum Midland Post treatment	Panicum virgatum Lowland Pre treatment	Panicum virgatum Lowland Post treatment	Poa pratensis Lowland Pre treatment	Poa pratensis Lowland Post treatment
One Pasture, Control								
Seasonlong	1	Grazed	1.1	1.1	0.0	0.1	0.2	0.2
n = 2		Ungrazed	2.2	2.4	0.0	0.0	0.0	0.0
Two Pasture, Switchback								
3 Grazing Periods	2	Grazed	0.5	3.2	0.2	0.1	0.3	1.4
n = 2		Ungrazed	0.6	2.2	0.1	0.6	0.2	0.2
4 Grazing Periods	3	Grazed	2.1	1.1	0.4	0.2	0.7	3.2
n = 2		Ungrazed	1.1	1.2	0.7	0.4	0.1	3.0
Three Pasture, Once Over								
Deferred	4	Grazed	6.4	2.1	2.0	1.6	2.2	7.1
n = 4		Ungrazed	3.3	3.9	0.4	2.1	2.8	5.8
Ungrazed	5	Grazed	5.5	2.7	7.9	2.9	2.1	5.7
n = 3		Ungrazed	2.7	2.5	3.7	1.7	2.1	3.7
Mid Season	6	Grazed	1.2	1.6	0.4	7.4	5.8	11.4
n = 1		Ungrazed	1.8	0.4	0.0	0.0	1.0	0.4
Three Pasture, Twice Over								
Early - Late	7	Grazed	0.9	0.9	0.5	2.6	6.2	12.5
n = 3		Ungrazed	2.1	2.7	0.7	4.3	1.1	4.8
Early - Mid	8	Grazed	2.0	1.2	2.7	2.7	4.2	5.6
n = 6		Ungrazed	4.2	3.0	2.5	1.8	2.4	1.4
Mid - Mid	9	Grazed	0.9	1.2	1.4	2.5	7.2	10.3
n = 5		Ungrazed	1.6	1.1	0.8	1.3	2.8	6.9
Mid - Late	10	Grazed	1.4	1.4	2.0	1.9	6.2	9.0
n = 5		Ungrazed	1.7	1.3	2.1	1.6	4.8	4.8





LEGEND

1. One Pasture, Seasonlong, Control
2. Two Pasture, Switchback, 3 Grazing Periods
3. Two Pasture, Switchback, 4 Grazing Periods
4. Three Pasture, Once Over, Deferred
5. Three Pasture, Once Over, Ungrazed
6. Three Pasture, Once Over, Mid Season
7. Three Pasture, Twice Over, Early-Late Season
8. Three Pasture, Twice Over, Early-Mid Season
9. Three Pasture, Twice Over, Mid-Mid Season
10. Three Pasture, Twice Over, Mid-Late Season

Left Point. Grazed Paired Plot

Right Point. Ungrazed Paired Plot

* P<0.05

\+ P<0.1

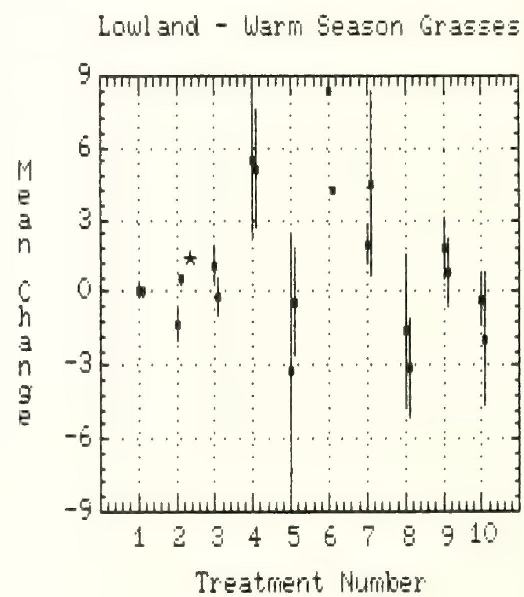
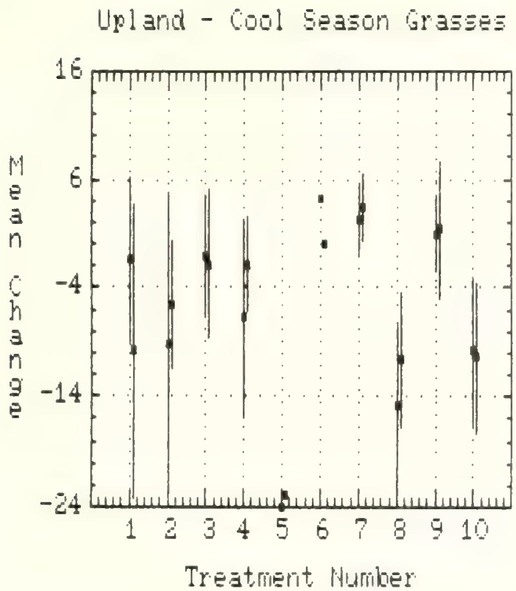
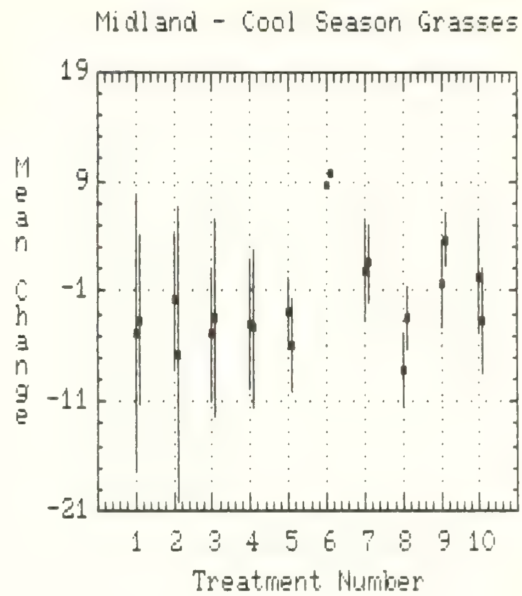


Fig. 1 Mean changes for warm season grasses in absolute basal cover between pretreatment and post treatment for ten grazing management treatments comparing grazed (point on left) and ungrazed (point on right) paired plots.





LEGEND

1. One Pasture, Seasonlong, Control
2. Two Pasture, Switchback, 3 Grazing Periods
3. Two Pasture, Switchback, 4 Grazing Periods
4. Three Pasture, Once Over, Deferred
5. Three Pasture, Once Over, Ungrazed
6. Three Pasture, Once Over, Mid Season
7. Three Pasture, Twice Over, Early-Late Season
8. Three Pasture, Twice Over, Early-Mid Season
9. Three Pasture, Twice Over, Mid-Mid Season
10. Three Pasture, Twice Over, Mid-Late Season

Left Point. Grazed Paired Plot

Right Point. Ungrazed Paired Plot

* P<0.05

\+ P<0.1

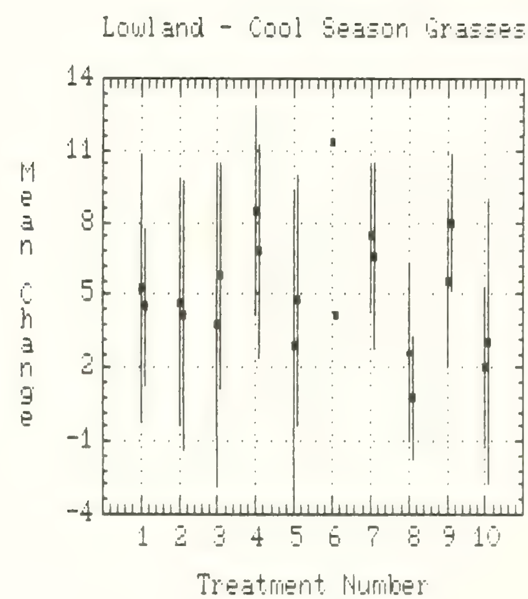
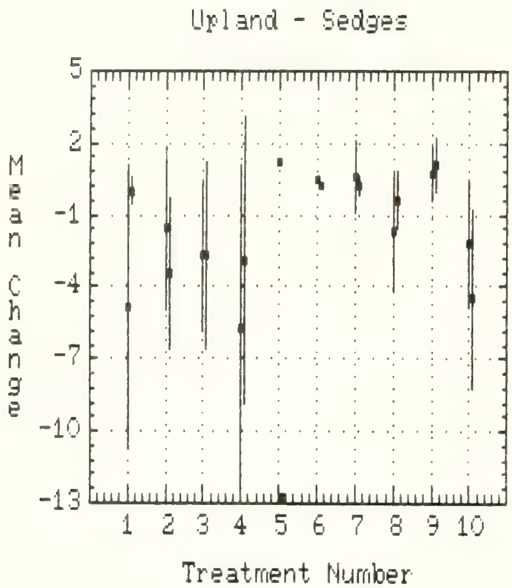
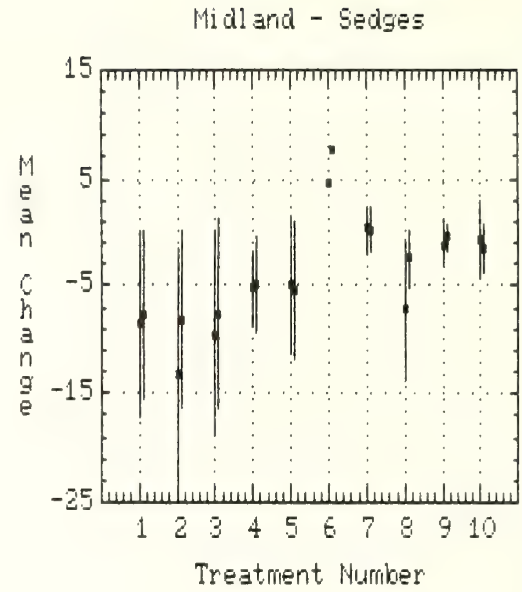


Fig. 2 Mean changes for cool season grasses in absolute basal cover between pretreatment and post treatment for ten grazing management treatments comparing grazed (point on left) and ungrazed (point on right) paired plots.





LEGEND

1. One Pasture, Seasonlong, Control
2. Two Pasture, Switchback, 3 Grazing Periods
3. Two Pasture, Switchback, 4 Grazing Periods
4. Three Pasture, Once Over, Deferred
5. Three Pasture, Once Over, Ungrazed
6. Three Pasture, Once Over, Mid Season
7. Three Pasture, Twice Over, Early-Late Season
8. Three Pasture, Twice Over, Early-Mid Season
9. Three Pasture, Twice Over, Mid-Mid Season
10. Three Pasture, Twice Over, Mid-Late Season

Left Point. Grazed Paired Plot

Right Point. Ungrazed Paired Plot

* P<0.05

\+ P<0.1

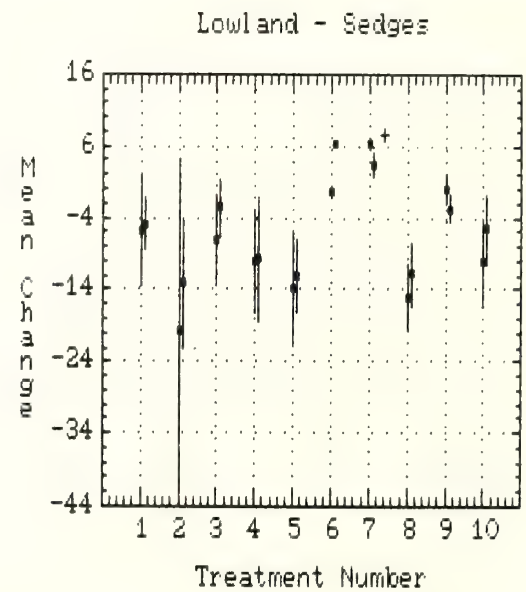
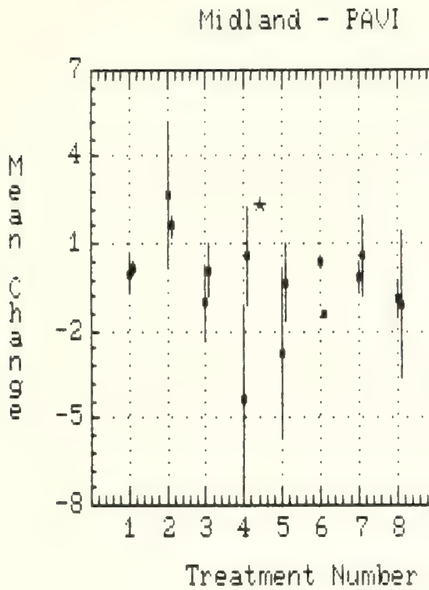


Fig. 3 Mean changes for sedges in absolute basal cover between pretreatment and post treatment for ten grazing management treatments comparing grazed (point on left) and ungrazed (point on right) paired plots.



LEGEND

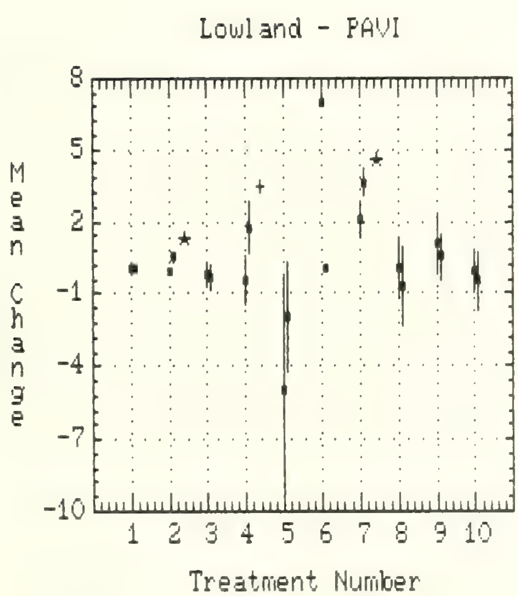
1. One Pasture, Seasonlong, Control
2. Two Pasture, Switchback, 3 Grazing Periods
3. Two Pasture, Switchback, 4 Grazing Periods
4. Three Pasture, Once Over, Deferred
5. Three Pasture, Once Over, Ungrazed
6. Three Pasture, Once Over, Mid Season
7. Three Pasture, Twice Over, Early-Late Season
8. Three Pasture, Twice Over, Early-Mid Season
9. Three Pasture, Twice Over, Mid-Mid Season
10. Three Pasture, Twice Over, Mid-Late Season

Left Point. Grazed Paired Plot

Right Point. Ungrazed Paired Plot

* P<0.05

\+ P<0.1



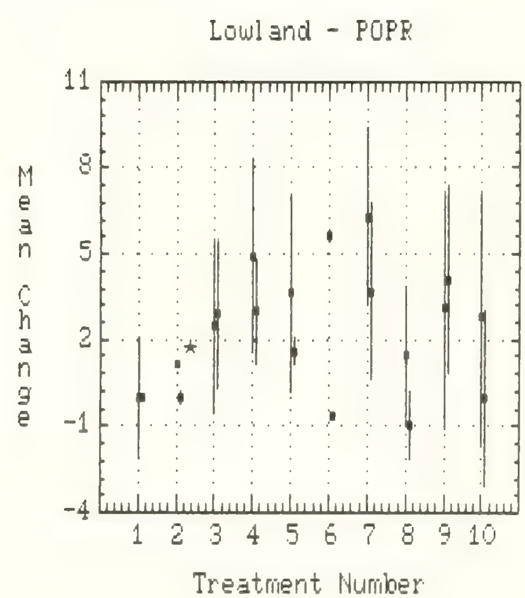


Fig. 4 Mean changes for Panicum virgatum (PAVI) and Poa pratensis (POPR) in absolute basal cover between pretreatment and post treatment for ten grazing management treatments comparing grazed (point on left) and ungrazed (point on right) paired plots.

basal cover in the lowland community decreased significantly (P<0.05) on the two pasture, thrice over treatment (#2) compared to the seasonlong treatment (#1). Basal cover of Panicum virgatum was significantly (P<0.05) increased in the lowland community on the three pasture, twice over grazed early and late season treatment (#7) compared to the seasonlong treatment (#1). Basal cover of Andropogon gerardi (Big bluestem), Andropogon scoparius (Little bluestem), Bouteloua gracilis (Blue grama), Calamagrostis inexpansa (Northern reedgrass), Koeleria pyramidata (Prairie junegrass), Stipa comata (Needleandthread), Stipa spartea (Porcupine grass), Carex heliophila (Sun sedge), Carex lanuginosa (Woolly sedge) and Juncus balticus (Baltic rush) did not change significantly (P>0.05) for the ten grazing treatments.

Relative changes in basal cover on management treatments comparing grazed and ungrazed paired plots showed no significant changes in vegetation after one year of treatment on the seasonlong treatments (#1) at significantly (P<0.05) lower stocking rates; or on two pasture, four times over (#3); three pasture, ungrazed (#5); three pasture, twice over grazed early-mid (#8); mid-mid (#9); and mid-late (#10) season treatments. Significantly negative effects on basal cover were shown by two pasture, thrice over (#2) and three pasture, once over, deferred (#4) treatments. Significantly positive effects on basal cover after one year of treatment was shown by the three pasture, twice over grazed early-late season (#7) treatments.

Visual obstruction measurements (VOM) were read spring and fall for 2 years along permanent transects in 17 pastures with 5 grazing treatments (table 7). The grazing management of the previous year (1978) for these pastures were the same as 1979 and 1980 for each treatment except one replication of the three pasture, once over grazed mid season treatment. It was grazed for two periods in 1978. The replications in the 3 pasture, deferred category were deferred until September only in 1979. In 1978, each pasture was grazed for two periods with the second period ending in early or mid September. These pastures were ungrazed from September 1978 until September 1979. The one period of deferred grazing occurred during the late season from September to mid November 1979. In 1980, these pastures were again grazed two periods.

The general trend for the visual obstruction measurements (table 7) was for the readings of spring 1979 to be the starting value with an increase due to growth for the fall of 1979. The readings of spring 1980 were below fall 1979 readings primarily because of fall grazing after the readings were taken and snow pack. The fall 1980 readings again increased above spring readings due to plant growth.

The readings on the permanent transects (table 7) of the one pasture, seasonlong treatments were generally below the other treatments. The 100% VOM of the one pasture treatments were significantly (P<0.05) below the two pasture, switchback; three pasture, mid season; and three pasture, twice over in spring 1979, the three pasture, deferred in fall 1979, and the three pasture, deferred; three pasture, mid season; and three pasture, twice over in spring 1980. The one pasture, seasonlong treatment was significantly (P<0.05) above the three pasture, deferred in fall 1980. The 100% VOM of the one pasture, seasonlong treatments were below the minimum of 1.5 decimeters in both spring 1979 and 1980. The 100% VOM of the three pasture, deferred treatment was not significantly different (P>0.05) from the other rotation treatments in spring and fall 1979 and spring 1980. The 100% VOM for the deferred treatment was significantly below (P<0.05) the one pasture, seasonlong; three pasture, mid season; and three pasture, twice over treatments in fall 1980. The 100% VOM fall 1980 for the three pasture, deferred treatment was below the minimum of 1.5 decimeters. The 100% VOM for the two pasture, switchback; three pasture, once over mid season; and three pasture, twice over were not significantly different (P>0.05) for spring and fall 1979 and 1980.

The 0% VOM (table 7) for the three pasture, deferred treatment was significantly greater (P<0.05) than the other treatments in fall 1979 and spring 1980. The 0% VOM were very similar (P>0.05) for all other treatments.

Visual obstruction measurements from the permanent transects of the seasonlong treatments had 100% readings significantly below other treatments during the spring and below the minimum of 1.5 decimeters required to provide adequate concealment cover. The three pasture, once over deferred treatments had vegetation that was significantly taller but not significantly denser in the fall prior to the deferred grazing period than the rotation treatments that had been grazed. In the spring after the deferred grazing, the 0% VOM was still significantly taller and the 100% VOM was not significantly different than the rotation treatments. At the end of the first growing season after deferred grazing, the 0% VOM was not significantly different and the 100% VOM was significantly below the readings from the rotation grazing treatments and below the minimum 1.5 decimeters. The visual obstruction readings for the two pasture, switchback, three pasture, once over mid season and three pasture, twice over treatments were not significantly different and the 100% VOM's were above the minimum 1.5 decimeter level. The seasonlong grazing treatment and the three pasture, deferred treatment did not satisfactorily provide adequate concealment cover for prairie grouse.

Table 7. Visual obstruction measurements in decimeters from permanent transects read spring and fall of 1979 and 1980 for 1, 2 and 3 pasture grazing treatments. Means of same column followed by the same letter are not significantly different (P<0.05).

Treatment	Percent visual obstruction	1979 Spring	1979 Fall	1980 Spring	1980 Fall
1 Pasture, Control					
Seasonlong	0%	3.45 ± 0.15z	5.20 ± 0.10z	4.30 ± 0.0z	4.95 ± 0.25z
n = 2	100%	1.15 ± 0.15a	1.65 ± 0.25a	1.30 ± 0.0a	2.00 ± 0.10a
2 Pasture,					
Switchback	0%	5.10 ± 0.44y	5.63 ± 1.22z	4.90 ± 1.39zy	4.55 ± 1.06z
n = 4	100%	1.75 ± 0.23b	1.85 ± 0.56ab	1.45 ± 0.21ab	1.48 ± 0.47ab
3 Pasture, Once Over					
Deferred, Late	0%	4.97 ± 0.26y	7.93 ± 0.12y	5.83 ± 0.72x	4.08 ± 0.87z
n = 4	100%	1.50 ± 0.29ab	2.17 ± 0.17b	1.65 ± 0.11b	1.20 ± 0.25b
Mid Season	0%	5.05 ± 0.15y		4.97 ± 0.80zy	4.90 ± 0.88z
n = 3	100%	1.80 ± 0.40b		1.80 ± 0.43b	1.80 ± 0.29a
3 Pasture, Twice Over					
Early-Mid-Late	0%	4.57 ± 0.83y	5.28 ± 0.82z	4.68 ± 0.36y	4.95 ± 0.65z
n = 4	100%	1.53 ± 0.05b	1.83 ± 0.18ab	1.73 ± 0.22b	1.85 ± 0.30a

Table 8. Visual obstruction measurements in decimeters from nonpermanent transects read spring of 1979 or 1980 for 1, 2, and 3 pasture grazing treatments. Means of same column followed by the same letter are not significantly different (P<0.05).

Treatment	0% Visual Obstruction	100% Visual Obstruction
1 Pasture, Control		
Seasonlong	3.87 ± 0.43z	1.20 ± 0.12a
n = 4		
2 Pasture,		
Switchback	5.00 ± 1.03zy	1.60 ± 0.26b
n = 8		
3 Pasture, Once Over		
Deferred, Late	5.58 ± 0.71yx	1.64 ± 0.10b
n = 5		
Ungrazed (Fall)	7.10 ± 1.03x	2.12 ± 0.17c
n = 5		
Mid Season	4.73 ± 0.53zy	1.62 ± 0.23b
n = 6		
3 Pasture, Twice Over		
Early - Late	4.80 ± 0.50y	1.55 ± 0.05b
n = 2		
Early - Mid	4.88 ± 0.56y	1.44 ± 0.33b
n = 5		
Mid - Mid	5.00 ± 0.70y	1.70 ± 0.16b
n = 6		
Mid - Late	4.10 ± 0.42zy	1.68 ± 0.15b
n = 4		

The 0% and 100% VOM from the nonpermanent transects (table 8) were read in the spring of 1979 or 1980 in 40 pastures with 8 treatments. The nonpermanent transects in the deferred treatment were also read in the fall after one year of ungrazed treatment prior to the deferred grazing period in mid September. The 100% VOM for the one pasture, seasonlong treatment was significantly below ($P<0.05$) all other treatments. It was the only nonpermanent transect reading below the minimum of 1.5 decimeters. The fall 100% VOM for the three pasture, ungrazed was significantly greater ($P<0.05$) than all other treatments. The spring readings on the deferred treatments were significantly reduced ($P<0.05$) from the fall readings on the same transects in the ungrazed treatment. The spring 100% VOM of the three pasture, deferred treatment were not significantly different ($P>0.05$) than the other rotation grazing treatments. The 100% VOM spring readings for the two pasture, switchback; three pasture, once over, midseason; three pasture, twice over, grazed early-late; early-mid; mid-mid; and mid-late season were not significantly different ($P>0.05$).

The 0% VOM for the three pasture, ungrazed treatment was significantly taller ($P<0.05$) than all other treatments in the fall. It did not retain this height in the following spring after fall grazing. The three pasture, deferred treatment was not significantly different ($P>0.05$) from the other rotation grazing treatments (table 8).

Visual obstruction measurements from the nonpermanent transects showed that the seasonlong treatment did not provide adequate prairie grouse concealment cover. The visual obstruction for the three pasture, once over deferred treatment appeared impressive before the grazing period began but was no different than the rotation treatments the following spring after the deferred grazing treatment.

There were 30 active prairie grouse display grounds in the spring of 1975 and 54 in 1980 (Manske and Barker 1981). Twenty-seven grounds were active for the entire six year study period. The location of these grounds changed from the previous year on the average 2.6 ± 1.4 times in six years. Only two display grounds remained on the same 10 acre area for the duration of the study. These two grounds moved within that area. All 54 display grounds observed during this study changed locations from the previous year 62% of the time.

This high rate of changing locations of display grounds was different from the traditional concept of permanent locations for prairie grouse display grounds. The reasons that the display grounds on the Sheyenne National Grasslands changed locations frequently was primarily due to a relatively young population that was increasing and expanding and had not developed long term traditional locations and location changes as a response to the various grazing management treatments.

Twenty-six (48%) of the display grounds active in 1980 were new after 1974. Thirty-four (63%) were new after 1972 and forty-four (81%) were new after 1968 when rotation type grazing management was started on the Sheyenne National Grasslands. Most of the prairie grouse population increase and expansion occurred after 1968. Large increases in the population occurred between 1968 and 1972, 1973 and 1975, and 1978 and 1979. Large expansions into previously unoccupied habitat occurred between 1973 and 1974, and 1978 and 1979. A large increase in density of males per square mile of occupied habitat occurred between 1978 and 1979.

Use index (Robel et al. 1970b) by display grounds of various grazing management treatments (table 9) indicates that display grounds have preferably moved into pastures of 2, 3 and 4 pasture systems that had been grazed 2, 3 or 4 periods the previous year. Pastures of 3 and 4 pasture systems that had been grazed for only one period in mid season or deferred until September were not preferably used by prairie grouse for courtship display. The one pasture, seasonlong treatment was also not preferably selected for courtship display.

Six prairie chicken and eight sharp-tailed grouse nests (table 9) were found on federal land during this study. Five prairie chicken and six sharp-tailed grouse nests were located in pastures of 3 and 4 pasture systems that had been grazed for 2 or 3 periods the previous year. Three of these prairie chicken and 3 sharp-tailed grouse nests were successfully hatched and 2 prairie chicken and 3 sharp-tailed grouse nests were not successful. One prairie chicken and one sharp-tailed grouse nests were located in pastures that had been deferred from grazing until September the previous year. The sharp-tailed grouse nest was successful but the prairie chicken nest was not hatched. One sharp-tailed grouse nest was located in a one pasture, seasonlong treatment. It was not successfully hatched. The majority (79%) of the prairie grouse nests found during this study were located in pastures that had been grazed for 2 or 3 periods the previous year.

SUMMARY

Grazing by domestic livestock on grasslands effects the plant communities differentially depending on season of use, intensity of grazing and duration of grazed and ungrazed periods. Prairie grouse depend on grassland plant communities to provide for their various habitat requirements. Prairie grouse populations respond to the differential changes in grassland vegetation resulting from various grazing management treatments.

Table 9. Use index for display ground locations and number of nest locations for 1, 2, 3 and 4 pasture grazing treatments.

Treatment	Use Index Display Grounds 1975 - 1980	Number of Nests Prairie Chicken	Sharp-tailed Grouse
1 Pasture, Control			
Seasonlong	0.72 ± 0.47	0	1
2 Pasture			
1 Over	1.05 ± 0.30	0	0
2, 3, & 4 Over	1.64 ± 0.17	0	0
3 Pasture			
Deferred, Late	0.53 ± 0.45	1	1
1 Over	0.84 ± 0.16	0	0
2 & 3 Over	1.06 ± 0.14	3	6
4 Pasture			
Deferred, Late	0.54 ± 0.54	0	0
1 Over	0.56 ± 0.06	0	0
2 & 3 Over	1.33 ± 0.29	2	0

Seasonlong grazing treatments showed no benefit to grass basal cover even at low stocking rates. Spring 100% visual obstruction measurements (VOM) were below rotation grazing treatments. These readings were below the minimum 1.5 decimeter level and did not provide adequate prairie grouse concealment cover for nesting or roosting. Prairie grouse select against seasonlong grazing treatments for spring courtship display ground and nest locations.

Two pasture systems with three grazing periods showed reduction in basal cover of warm season grasses and switchgrass on the lowland plant community. These decreases were greater on the two pasture, thrice over treatments than on the seasonlong treatments. Basal cover of vegetation on the two pasture, four times over was not significantly changed. Pastures in two pasture treatments should be managed with no less than four grazing periods. Spring 100% VOM readings were greater on two pasture treatments than one pasture, seasonlong treatments and were not different than readings from three pasture rotation treatments for permanent and non-permanent transects. Prairie grouse selected pastures managed with two pasture grazing treatments for courtship display locations but not for nest site locations.

Pastures grazed for one period during mid season, June to September, showed no positive response in grass basal cover but did show significantly greater 100% VOM readings compared to seasonlong grazing treatments. Prairie grouse did not select for pastures managed with one mid season grazing period for display ground and nest locations.

Three pasture, once over deferred grazing treatments had 11 to 13 months of ungrazing prior to the deferred grazing treatment. No changes in basal cover of the vegetation occurred during this one year ungrazed period. The vegetation height did visually appear to be impressive as prairie grouse habitat after one year of ungrazing. The 0% VOM was significantly taller than grazed treatments but the 100% VOM was not different than rotation grazed treatments. After 60 days of grazing during the late season, the 0% VOM was reduced but still taller than the other treatments and the 100% VOM was greatly reduced but not different than rotation treatments in the spring. The deferred grazing treatment was intended to delay grazing pressure on one pasture in a system until after grass seed development which occurrs by late August or early September for the purpose of improving grass plant density but deferred grazing decreases basal cover of warm season grasses and reduces basal cover of switchgrass on the midland and lowland plant communities. The 100% VOM was significantly decreased during the first growing season after deferred treatments and the level fell below the minimum of 1.5 decimeters. Prairie grouse select against pastures managed with deferred grazing the previous year for spring display ground locations. Deferred grazing is not a desirable grazing treatment for grassland vegetation and prairie grouse.

Three pasture, twice over treatments were grazed early-late, early-mid, mid-mid, and mid-late season of use. Warm season grasses and switchgrass on the midland and lowland communities and sedges on the lowland communities increased in basal cover on pastures managed with two grazing periods compared to pastures managed with one pasture, seasonlong treatments. The 100% VOM on pastures with two grazing periods was significantly greater than on pastures grazed seasonlong. Prairie grouse select for pastures with two or three grazing periods for display

ground and nest locations. Management treatments with the pastures grazed for two periods showed benefit to grassland vegetation, prairie grouse habitat and prairie grouse populations. Treatments with twice over grazing on each pasture should be used to manage the allotments on the Sheyenne National Grasslands.

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Abstracts

GRASSLAND HABITAT TYPES OF THE SHEYENNE DELTA - Bill Barker, Mario Biondini, Lee Manske and Tim Nelson, North Dakota State University

The grassland vegetation of the Sheyenne Delta in southeastern North Dakota was characterized according to habitat type based on concepts and methods developed by Daubenmire. Detrended Correspondence Analysis (DCA) was used to summarize the species composition and identify the habitat types. The number of significant ordination axis was determined with the use of the Fisher's proportion test. The habitat types identified through DCA were tested for statistical significance with the use of the Kruskal-Wallis statistics. Five grasslands habitats were described: 1) Stipa comata - Carex heliophila h.t., 2) Andropogen hallii - Calamovilfa longifolia h.t., 3) Bouteloua gracilis - Stipa comata h.t., 4) Andropogon gerardi - Andropogon scoparius h.t., and 5) Carex lanuginosa - Calamagrotis stricta h.t.

MANIPULATION OF HABITAT BY FIRE AND MOWING - Bill Barker and Lee Manske, North Dakota State University; and Ken Higgins, South Dakota State University

The effects of spring burning (1 May) and 3 mowing treatments (1 June mow, 1 July mow and 1 August mow) on the floristic composition and utilization by livestock of the Carex lanuginosa - Calamagrostis stricta habitat type were studied. Repeated spring burning eliminates woody species from this habitat type but increases livestock utilization from about 10% to 60%. Repeated mowing eliminates woody species but does not increase utilization by livestock as much as spring burning. July 1 is probably the best time to mow to gain increased livestock utilization and obtain high quality hay. We recommend a change from grazing the 3 pasture deferred rotation grazing systems once-over to grazing 2 pastures twice-over and 1 pasture once-over. Spring burning and mowing are effective in getting better livestock utilization.

U.S. Department of Agriculture
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General Technical
Report RM-160

Recent Historical and Projected Regional Trends of Trout in the Southeastern United States

Patricia A. Flebbe
Thomas W. Hoekstra
Noel D. Cost

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Flebbe, Patricia A.; Hoekstra, Thomas W.; Cost, Noel D. 1988. Recent historical and projected regional trends of trout in the Southeastern United States. General Technical Report RM-160. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 19 p.

The recent history of trout in the Southeastern United States is described. A statistical relationship established between current trout density and land use and forest cover in watersheds is the core of a projection tool that evaluates impacts of expected future and alternative timber management on trout for regional and national assessments.

Keywords: Multiresource analysis, regional model, Southeast, statistical model, trout, trout habitat

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Recent Historical and Projected Regional Trends of Trout in the Southeastern United States

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Abstract

This research was motivated by the need for regional assessments of fish resources in a multiple resource context. The current and historical status of brook, brown, and rainbow trout in the Southeastern United States was reviewed. To analyze effects of projected land use changes and timber management alternatives on trout, a fish model was developed within a multiple resource framework that links fish, forage, wildlife, and water to land use and timber. Discriminant function analysis was used to determine the relationship between trout density classes and runoff, land use, and forest cover in coldwater watersheds of the region. Projected land base changes for a baseline and several alternative scenarios were applied to the trout model to assess impacts of various economic assumptions and timber management decisions. Over the 50-year projection period, trout density declined in response to increased human land use acreages and decreased old-age hardwood acreages for all scenarios. The feasibility of a regional approach to analysis of trout habitat relationships was demonstrated. This research points to the need for management of trout on a regional scale, in a multiple resource context, as well as at the stream level.

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Contents

Recent Historical and Projected Regional Trends of Trout in the Southeastern United States

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INTRODUCTION

The Forest and Rangeland Renewable Resource Planning Act of 1974 (RPA)[2] as amended by the National Forest Management Act of 1976 (NFMA)[3] requires that the USDA Forest Service make decadal national assessments of renewable natural resources. Wildlife and fish are specific resource categories to be evaluated in the RPA assessment.

The first assessment, in 1975 (USDA FS 1977), prepared shortly after enactment of the RPA and NFMA, was organized according to fish and wildlife uses, including a brief section on fishing. Fishing was identified as one of the most popular and fastest growing outdoor recreation activities, and management opportunities for improving fish supply were limited.

In the 1979 assessment document (USDA FS 1981), supplies of and demands for selected fish species were compared in a largely descriptive manner. The emphasis was on the current situation (mid-1970's), with a few references to historical supply or demand. Participation in major fishing activities (i.e., saltwater and freshwater fishing by region) was projected from 1977 to 2030. Freshwater fishing participation in the Southeast was projected to increase 20% by 1990 and 106% by 2030 over 1977 levels, compared to increases of 18% and 90%, respectively, for the nation as a whole. Increasing importance of stocking and aquaculture to meet the demand for fish was noted. Implications of not meeting demands for both commercial and recreational users, problems in improving the status of fish, and opportunities to maintain and enhance the fish resource were discussed. In the final section, the authors noted that, except for a few important commercial and recreational species, little quantitative supply or demand information was available (USDA FS 1981:151). Fish population estimates were particularly rare. Two major criticisms of the 1979 assessment were (1) lack of analytical capability, and (2) resources were addressed independently rather than with multiple resource analyses (Schweitzer et al. 1981).

Since that assessment, technical specifications for the next national assessment of wildlife and fish, in 1989, have been described. For purposes of organizing the 1989 assessment, Hoekstra and Hof (1985) identified four major attributes of wildlife and fish resources—population, habitat, harvest, and users—and interpreted the national assessment specified in the 1974 RPA as requiring three tasks:

1. Summarize the current and historical inventory or production and use or consumption of timber, range, wildlife, fish, water, and recreation resources.
2. Project future multiresource inventory or production and use or consumption patterns from the current situation.
3. Analyze opportunities for improving the future resource inventory or production and use or consumption situation.

Tasks 2 and 3 both require analytical tools that can project the future supply and demand of the renewable resources by extending historic patterns (Task 2) and by constructing alternative futures (Task 3). Such analytical tools, or models, were needed for the 1989 assessment.

The objective of this research was to develop a model, based on current estimates of fish populations, that would be capable of projecting future fish production. The model and projections operated within a framework (Joyce et al. 1986), described below, intended to link multiple resources toward achieving the kinds of analyses prescribed in Task 3.

Landscape ecology recognizes the need for resource agencies to develop databases and management strategies at appropriate spatial scales to minimize problems of within-system heterogeneity (Risser et al. 1984). A national level model was not practical for resources, such as fish species, whose distributions are not national. Capturing sufficient detail about resource response to management for all lands across the United States has proven to be too cumbersome for one model that includes many different management activities on many ecosystems (Joyce et al. 1986). At the regional scale (i.e., several states), we can consider fewer ecosystem types, more similar in structure and function, than at the national scale. Within a region, we can address a common set of ecological and socioeconomic factors, which exert the most significant effect on likely future resource production (Joyce et al. 1986). Models developed at regional levels can be integrated across multiple resources to produce regional assessments and, ultimately, aggregated into a national assessment. The Forest Service Southern Region was selected for pilot development of regional models in a multiresource framework (Joyce et al. 1986) because potential conflicts among land use

[2] *Public Law 93-378. United States Statutes at Large. Volume 88, p. 476 (P.L. No. 93-378, 88 Stat. 476).*

[3] *P.L. No. 94-588, 90 Stat. 2949.*

requirements in the South had been identified (Alig 1984) and because multiple resource data were available. The South was divided into Southeast and South Central subregions based on Forest Service Forest Inventory and Analysis (FIA) units assigned to the Forest Service Southeastern and Southern Experiment Stations, respectively.

This report summarizes the current and historical populations and natural history of trout for the Southeast (Task 1). Although trout are present in the Appalachian mountain areas of the South Central subregion (Bivens et al. 1985), population data were not available, and the trout population analysis presented here is limited to the Southeast. Hereafter, region will refer only to the Southeast. Setting the context for development of the projection model, the next section outlines the multiple resource framework (Joyce et al. 1986) as it relates to the trout model structure, and briefly reviews models of trout-habitat relationships. The model we developed to capture regional trout-habitat relationships from the current situation is described, and model response under a baseline projection of the future is presented (Task 2). Although tradeoffs among all renewable resources are not considered in the analysis of alternative futures (Task 3), impacts of various timber management opportunities on the trout population are evaluated. Complete analysis under Task 3 requires analysis of habitat, user, and harvest attributes; some of those analyses will be addressed in other reports (e.g., Hof and Baltic 1988) and the 1989 assessment. Finally, implications for regional management of trout fisheries and research opportunities are discussed.

Figure 1.—Present distribution of all trout species in the Southeast. The darkly shaded area represents the area surveyed by North Carolina and Virginia that constitutes the area for which the regional trout model was calibrated. The lightly shaded area shows where trout are known to occur but where no abundance data were available. Projections are made for both shaded areas.

CURRENT STATUS AND RECENT HISTORICAL TRENDS

Current Resource Situation

Brook trout (*Salvelinus fontinalis*) are native to the Southeast, where their range extends into northeast Georgia (Lee et al. 1980). Rainbow trout (*Salmo gairdneri*) and brown trout (*Salmo trutta*) were introduced into coldwater streams of the region. During the late 1970's, several states in the Southeast made surveys of their trout resources. Virginia and North Carolina, the states with most of the trout streams in the region, made detailed surveys of trout abundance in streams that form the database for the research reported here. Georgia also supports a trout fishery, but abundances were not inventoried (Fatora and Beisser 1980). A very small corner of South Carolina has approximately 25 streams (200 miles) classified as coldwater habitat (USDI FWS 1983). Florida has no trout streams (fig. 1).

In Virginia, the 41 westernmost mountain counties support coldwater fisheries (Neal 1980). The state survey identified 2029 miles (446 streams) of wild trout streams, of which 67% were pure native brook trout, and an additional 946 miles of coldwater streams suitable for stocking (Neal 1980). Of this latter category, only 29% was actually trout fishery at the time of the survey (Neal 1980). Brook trout are scattered throughout the Virginia coldwater area, but predominate in three high-altitude physiographic regions: the Blue Ridge mountains, including Shenandoah National Park; the Blue Ridge plateau-Mt. Rogers area to the southwest, including parts of Jefferson National Forest; and the Allegheny highlands bordering West Virginia, especially on George Washington National Forest lands (Neal 1980). Wild rainbow trout (i.e., naturally reproducing) occur in about 20% of the trout streams, and wild brown trout in a very small number of streams (Neal 1980).

The North Carolina survey of 26 western mountain counties estimated that approximately 4000 miles of streams, at elevations over 1500 ft, were capable of supporting trout (Bonner 1983). Although trout abundance was determined in the trout stream survey, a state trout population estimate is not appropriate without an estimate of total habitat presently occupied.

Georgia classifies 2393 miles of primary trout streams, which contain naturally reproducing trout populations, and 1594 miles of secondary trout streams, which sustain nonreproducing trout year-round (Fatora and Beisser 1980). All trout streams are located in 31 counties of northern Georgia. The southernmost trout fishery in the Southeast is found in the tailwaters of the Buford dam on the Chattahoochee River, north of Atlanta (Hess

1980). Since the introduction of brown and rainbow trout, brook trout have disappeared from all but about 50 streams (87 miles), mostly in Rabun, White, and Union counties of Georgia (England 1979).

All Southeastern States (fig. 1), except Florida, stock trout. Both state and national fish hatcheries produce trout for stocking in the region. Regionally, more adult trout than fingerlings are stocked from the USFWS National Fish Hatcheries[4] in most years (fig. 2). Since 1965, fingerlings stocked have fluctuated between about 500,000 in 1965–1967 and 1985 up to nearly 2.5 million in 1980, while numbers of catchable trout increased from 1.2 million to about 2.0 million per year in the 1970's (fig. 2). Since 1983, stocking of both fingerlings and adults from the National Fish Hatcheries has declined, due to changes in distribution priorities.[4] Most stocked trout were rainbow trout, followed by brown trout (fig. 3). Georgia received most of the fingerlings stocked in the region during 1978–1980, and Virginia, relatively few; stocked adults were relatively evenly distributed among the 4 states, not in proportion to available habitat (fig. 4). Brown trout were not stocked in Virginia until the

[4] *United States Department of the Interior, Fish and Wildlife Service. Propagation and Distribution of Fishes from the National Fish Hatchery System, Report numbers 2-20 for fiscal years 1965 and 1966 through 1985.*

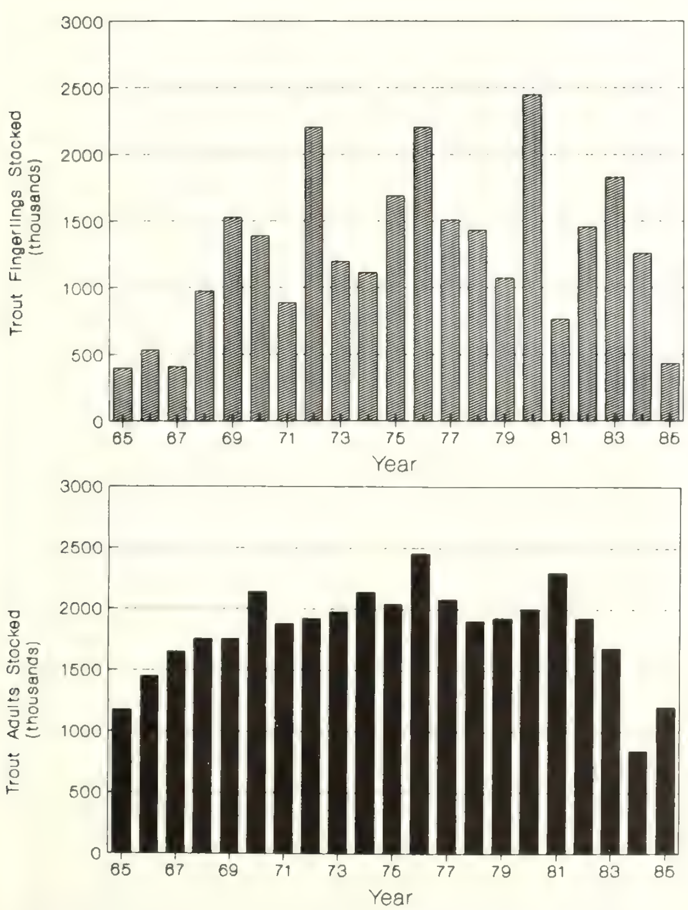

Figure 2.—Numbers of (a) fingerling and (b) adult (sexually mature) trout distributed to Southeastern States from the USDI National Fish Hatcheries 1965–1985.[4]

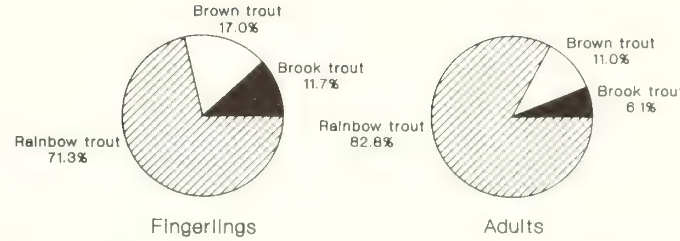

Figure 3.—Percent of fingerling and adult trout distributed during 1978–1980 by species to the Southeastern States from the USFWS National Fish Hatcheries (Source: USDI FWS, Propagation and distribution of fishes from the National Fish Hatchery System).

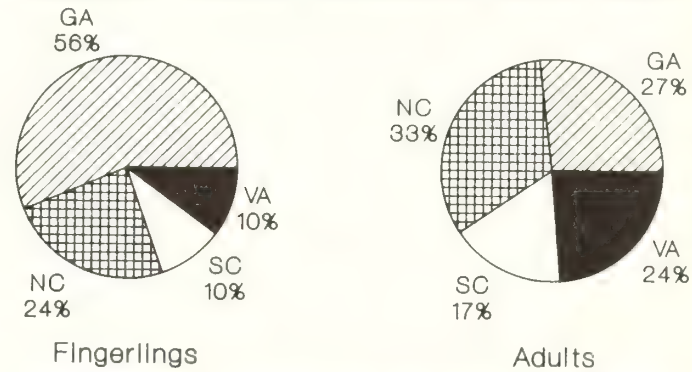

Figure 4.—Percent of fingerling and adult trout distributed during 1978–1980 by state to the Southeastern States from the USFWS National Fish Hatcheries. No trout are distributed to Florida (Source: USDI FWS, Propagation and distribution of fishes from the National Fish Hatchery System).

1960's, and continue to be a minor component (<6%) of state hatchery production (Neal 1980). In summary, the trout populations in the region are maintained by stocking, although, in the more northern and mountain areas of North Carolina and Virginia, more streams have reproducing populations, and stocking is less important (Neal 1980, Bonner 1983).

Both numbers of recreational freshwater fishing participants and their expenditures have been increasing nationally (table 1) (USDI FWS and USDC Bureau of Census 1982).[5] In 1980, 188,900 people fished for trout in Georgia, 204,300 in North Carolina, 45,800 in South Carolina, and 189,400 in Virginia.[6] By comparison, in the mid-1970's, trout anglers numbered 130,852 in North Carolina, 55,208 in South Carolina, and 133,662 in Virginia.[7] Trout license sales for Georgia have fluctuated between 87,000 and 100,000 during 1981–1984; North Carolina trout license sales have declined from 51,000 in 1981 to 45,000 in 1984; and Virginia trout license sales have increased from 112,000 in 1981 to 115,000 in 1984.[8]

[5] *Initial findings of the 1985 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, U.S. Department of the Interior news release dated March 21, 1987.*

[6] *State reports for Georgia, North Carolina, South Carolina, and Virginia, prepared from the 1980 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census, undated. 76 or 77 p. each.*

[7] *Data assembled for the 1979 assessment by the Forest Service from numbers provided by other federal agencies and the states.*

[8] *Vital Statistics for 1980, 1981, 1982, and 1984, compiled by the Southeastern Cooperative Fish and Game Statistics Project for the Southeastern Association of Fish and Wildlife Agencies.*

Table 1.—Trends for freshwater fishing participation and expenditures in the United States, 1965–1985. Expenditures per participant indexed to 1975 dollars with gross national product price deflators.

Year	No. of participants (thousands)	Expenditures Total (millions)	Per participant (1975 dollars)
1965	23,962	$2,126	$151
1970	29,363	$3,734	$175
1975	36,599	$8,702	$238
1980	37,081	$14,441	$274
1985	40,200	$19,556	$264

Source: U.S. Fish and Wildlife Service and U. S. Bureau of Census, 1982.[5]

On National Forests in the Southern Region, total coldwater fishing user days have increased from less than 600,000 in the late 1960's to nearly 800,000 in the early 1980's.[9] In general, trout fishing participants have increased in the past decade in the Southeast.

Historical Resource Situation

Trout populations have not been inventoried systematically in the past for any large areas of the Southeast. Thus, the past history of trout populations cannot be described for the region in a quantitative manner.

The history of trout in the Great Smoky Mountains National Park in the southern Appalachian Mountains, on the border between North Carolina and Tennessee, has been analyzed. At the turn of the century, brook trout were found at elevations down to about 2000 feet in the area of North Carolina that was to become the Great Smoky Mountains National Park (King 1937). In the Smoky Mountains, rainbow trout stocking began about 1900 and became heavy after 1910 (Lennon 1967). By the 1930's, brook trout in the park area were restricted to headwaters above 3000 feet due to a combination of factors including logging, fires, overfishing, and stocking of rainbow trout (Powers 1929, King 1937). This restricted distribution continued to shrink with concomitant increases in rainbow trout distribution (Lennon 1967, Kelly et al. 1980, Larson and Moore 1985, Moore et al. 1986). In headwater streams, brook trout abundance is low and body size is small, suggesting a suboptimal habitat (Lennon 1967). Rainbow trout do not successfully invade the headwaters because a combination of factors limits their success: (1) presence of falls or cascades; (2) small stream water volume; (3) low temperatures, especially freezing temperatures in small streams; and (4) low pH (King 1937, Kelly et al. 1980, Moore et al. 1986). Zones of sympatry occur (Powers 1929, King 1937, Lennon 1967, Larson and Moore 1985, Moore et al. 1986). Overall, brook trout range in Great Smoky Mountains National Park was reduced by 70% by the mid-1970's (Kelly et al. 1980).

[9]*U.S. Department of Agriculture, Forest Service, Wildlife and Fish Habitat Management in the Forest Service for Fiscal Years 1967 through 1984, Washington, D.C.*

Similar changes have been reported for North Carolina, in general (Seehorn 1979). Since 1950, brown trout introduced at lower elevations in North Carolina have also migrated upstream, reducing the rainbow trout distribution (Kelly et al. 1980). Restoration projects in North Carolina and Georgia have found some recovery of brook trout populations after removal of rainbow trout (England 1979, Moore et al. 1983, Moore et al. 1986). In Virginia, brook trout appear to have been resistant to invasion by nonnative trout except for some invasion of rainbow trout in the southwest part of the state (Neal 1980). In Shenandoah National Park of northern Virginia, rainbow trout were reported to be limited in distribution and abundance (Lennon 1961).

MODELING APPROACH

The Multiresource Framework

Traditionally, fish have been related to their immediate environment, the stream. However, streams are imbedded within the landscape of the watershed, and the stream environment is affected by land use activities within its watershed. For multiple resource analysis and planning at the regional scale, fish habitat relationships in streams are not adequate, and the fish habitat must be extended to the watershed.

This research, to develop a modeling approach for regional analysis of fish resources, is part of a larger program, outlined by Joyce et al. (1986), for producing regional multiresource models toward a national assessment of renewable resources. This study is also designed to assess resource response to projected future land use and timber growth and yield in the Southern United States.[10] Fish, wildlife, forage, and water were identified as resources that depend on the same land base as does timber, and that might be affected by changes in land use and land cover patterns (Joyce et al. 1986).

To incorporate these other resources in the analysis, a multiple resource framework was designed (Joyce et al. 1986) that links forage, fish, wildlife, and water to the Southern Area Model (SAM) and Timber Resource Inventory Model (TRIM) (fig. 5). The Southern Area Model (Alig 1984) projects changes in acreages of cropland, range and pasture land, human land uses (urban, roads, farm structures, etc.), and major forest cover types (upland hardwoods, lowland hardwoods, mixed oak-pine, natural pine, and planted pine) for each state in the Southeast. On forest cover type acreages projected for the Southeast by SAM, TRIM simulates timber growth and yield to reflect timber management decisions (Tedder 1983, Tedder et al. 1987) required to meet harvest demands from a Timber Assessment Market Model (TAMM) (Adams and Haynes 1980). TRIM produces timber stand inventories for homogeneous cells that represent all stands of a given forest cover type, age class, ownership, site class, and stocking class. The three policy models (TAMM, TRIM, and SAM) make projec-

[10]*The South's Fourth Forest: Alternatives for the Future, draft document, USDA Forest Service, Washington, D.C., 1986. 365 p. + appendices.*

tions of the future land use acreages and timber inventories for baseline and alternative scenarios.

The other resource models (fig. 5), including the fish model, are intended to evaluate the effects of the land use changes and timber management on their respective resource. The resource models are linked by the common land base. In this framework, common land base refers to the common description in terms of land use and timber resource described above, rather than the more stringent requirement that all models operate on the same geographic unit (e.g., Forest Service region, state, county, watershed). Each resource operates on the geographic unit that is logical and appropriate for the resource, and all geographic units listed above are represented in the framework. For the fish resource, a watershed unit is the most appropriate geographic unit for three reasons: (1) a watershed unit allows the model to capture the relationship between trout and habitat at a regional scale; (2) the immediate environment for trout is the stream, and watersheds are the associated land unit for streams; and (3) the watershed unit, the geographic unit of the water quantity model, allows changes in water yield to be incorporated in the fish response. The watershed unit provides the means for incorporating both direct and indirect impacts of land base changes. Within the multiresource framework (fig. 5), there is no analysis of how management for fish influences timber; thus, this is an impacts analysis for fish. The analysis will identify changes in the land base that may create changes in the fish population.

The objective for this research, stated above, was refined to include the requirement that the analytical tool must operate within the framework just outlined: To develop a regional model based on current estimates of trout production that is capable of projecting future trout production from projected changes in land use and the timber resource within the multiple resource framework (fig. 5).

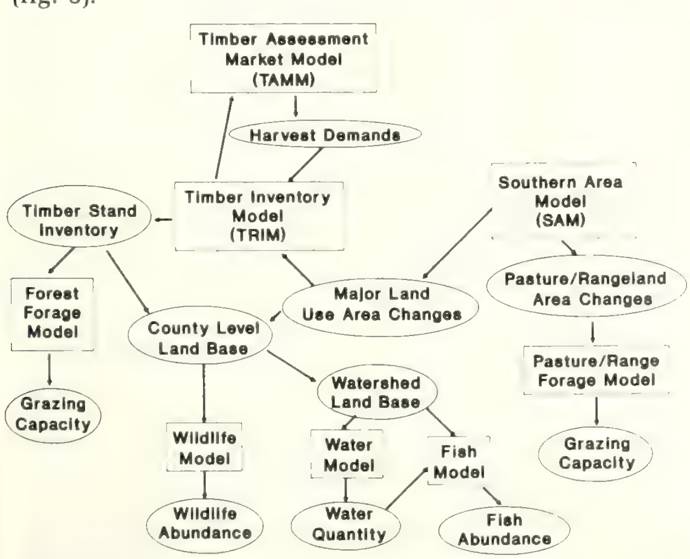

Figure 5.—Multiple resource model framework for linking individual resource models at the regional level. Boxes are models and ellipses are databases and model outputs. Arrows represent information transfers among resource models. (After Joyce et al. 1986.)

Trout Habitat Models

Few regional models, on the scale of several thousands of square miles, that relate fish abundance to land use and forest cover in the watershed habitat have been developed. Even site-specific stream models that predict fish abundance from habitat characteristics are rare compared to terrestrial wildlife habitat models (Hawkes et al. 1983). A few habitat models, such as the Fish and Wildlife Service Habitat Evaluation Procedures (HEP) (USDI FWS 1980), make predictions for current habitat conditions but predict suitable habitat rather than fish populations. In an analysis of streams in the southern Appalachian Mountains of North Carolina and Tennessee, the null hypothesis of no relationship between trout abundance or biomass and HEP physical habitat indices (e.g., weighted usable area, WUA) was rejected for some species' life stages (Loar et al. 1985). These habitat models do not include biological interactions between species and may not be appropriate to all management questions (Loar et al. 1985).

Multivariate statistical techniques are particularly well suited for habitat analyses (Shugart 1981) and, properly designed, can produce resource predictions. Some local level stream models have implemented statistical procedures, commonly correlation or regression analysis, to predict present fish population size in a stream from a suite of biologically or ecologically meaningful variables. For example, Binns and Eiserman (1979) modeled Wyoming trout stream standing stock with 10 factors that measured various aspects of flow, temperature, nitrogen, substrate, cover, and stream width. Burton and Wesche (1974) identified stream flow and watershed drainage, elevation, forested area, and total basin stream length as factors significantly related to trout standing stock in nine Wyoming streams and rivers. Harshbarger and Bhattacharyya (1981) used factor analysis to identify cover variable factors for small trout streams in western North Carolina and used regressions to relate these factors and the original variables to trout standing stock.

Site-specific models of trout abundance were deemed inappropriate for the national scope of the RPA assessment (Hawkes et al. 1983). Models developed for one spatial scale (e.g., a stream) cannot generally be applied to another disparate scale (e.g., the Southeast) (Risser et al. 1984). Available site-specific models of trout abundance also suffer one or more of the following disadvantages:

1. Models require detailed stream habitat data not available in state or regional inventory databases (e.g., stream cover, substrate, bank condition, Harshbarger and Bhattacharyya 1981).
2. Independent (predictor) variables are not related to land use or water quantity variables that link resource models to policy models in the framework of figure 5.
3. Models were developed for streams geographically removed from the Southeast and are not transferable (e.g., Binns and Eiserman 1979, Burton and Wesche 1974).

To overcome the first two disadvantages and implement these models in the regional framework outlined above would require intervening models that relate inventory descriptions and land projections to stream habitat characteristics. A direct approach is preferred. Transferring models from other regions of the country is not feasible because those models are specific to the issues appropriate to their region and not to the objectives of this analysis.

The goal of the trout model is to produce a regional predictive model of the fish resource based on current land use, timber cover, and water quantity. Because we have no known functional, or mechanistic, relationships between land use or water characteristics and fish production at this scale, we have chosen a statistical approach to the problem. The approach is similar to one used for regional wildlife models (Klopatek and Kitchings 1985, Flather et al. in press). An appropriate sampling unit must first be selected with a statistical approach. Ideally, sampling units are small enough to minimize problems of spatial heterogeneity in landscapes (Risser et al. 1984) and to provide sufficient sample size for multivariate analysis. In the framework described above, the fish resource model is linked to a water quantity model that projects runoff for watersheds above U.S. Geological Survey (USGS) gauging stations. To implement the linkage, the same watersheds were used as sampling, and geographic, units for the trout model.

To establish statistical relationships between trout abundance and land use, timber cover, and runoff, we chose to use discriminant function analysis rather than a multiple regression model because a discriminant function model minimizes the impact of several data assumptions we made (discussed below). Discriminant function analysis has been used to produce statistical models for both descriptive and predictive purposes (Williams 1983). This trout model uses a discriminant function analysis to develop a classification from the land and water data, capable of predicting trout abundance class membership from land use and water quantity projections.

REGIONAL TROUT MODEL

Water and Land Area Databases

The U.S. Geological Survey gauges define the watersheds for the trout model. Watersheds were selected from the set of USGS gauging stations by a number of criteria intended to meet three major objectives: (1) high-quality flow data were obtained during 1977 and for at least 5 years during 1973–1983; (2) no watersheds were nested in others; and (3) watersheds between 100 and 700 square miles in area, roughly the size of counties from which the land base is derived, were preferred. The total range of watershed size for the coldwater fish model was 39 to 3050 square miles; but, 85% of the watersheds fell in the 100–700 square mile range. Watershed sizes were distributed uniformly across trout abundance classes.

Annual average instantaneous flows (cubic feet per second) recorded by the USGS gauges over the period 1973–1983 were converted to acre-feet per acre-year to standardize for drainage area and to produce a measure that could be applied to the watershed as a unit. Thus, water quantity is a measure of runoff (ft/yr).

The watershed land use and land cover data were derived from county land use and land cover data obtained from the Soil Conservation Service (SCS) National Resource Inventory (NRI) (USDA SCS and Iowa State University Statistical Laboratory 1987) and the Forest Service Forest Inventory and Analysis (FIA) (USDA FS 1985) surveys. Estimates of total county land and water area were obtained from the U.S. Bureau of Census (USDC Bureau of Census 1970). The FIA inventory provided area estimates of commercial forestland for forest cover types (natural pine, planted pine, oak-pine, upland hardwood, and lowland hardwood) and forest age class; the NRI inventory supplied estimates of all other land types (crop, pasture, range, and human land uses). Combining the FIA and NRI inventories to characterize total county land area resulted in discrepancies when compared with Bureau of Census estimates of total county area because the two inventories are not mutually exclusive. The FIA and NRI databases were adjusted by iterative proportional fitting (Deming and Stephan 1940), called "raking," to approximate total county land area reported by the Bureau of Census. Proportions of each county contributing to each watershed were determined by planimetry or extracted from a digitized database of county-USGS Hydrologic Cataloging Unit intersections.[11] Acres from each county-watershed intersection were summed for each watershed by land use, then converted to proportions of each watershed in the NRI land use and FIA land cover categories.

The NRI and FIA categories were aggregated into the commonly defined land use and land cover categories to form, with USGS runoff estimates, the suite of independent variables that describes the current land base and runoff for the model (table 2). In this current inventory (1982), the coldwater watersheds, in the Appalachian Mountains and higher areas of the Piedmont, have very little planted pine (1.1% of the current inventory land base) and lowland hardwood forest (0.5%)—two forest types that are much more common in other areas of the Southeast region. Natural pine forest (9.9%), human land use (7.2%), and cropland (4.8%) are also less common in the coldwater area. In contrast, pastureland (18.9%), total forestland (65.5%), mixed oak-pine (8.0%), and, particularly, upland hardwood forests (45.9%) are more common than in the Southeast as a whole. Most of the additional acreages of upland hardwoods are in the two older age classes.

Fish Database

Regional fish models are limited by the availability of suitable databases. In most cases, data were collected by state agencies for various purposes, and adjustments

[11]*Computer tape and documentation produced by Robert G. Edwards and others, Oak Ridge National Laboratory, Oak Ridge, TN, 1983.*

Table 2.—Definition of independent variables used to develop the regional trout model. RUNOFF was transformed by natural log, and land use and land cover variables were proportions transformed by arcsine-square root to meet the normality assumption.

Variable acronym	Variable definition
RUNOFF	average over 1973–1983 of mean annual flow (acre-ft acre^{-1} yr^{-1})
TOTCRP	total cropland, including estimates of row crops, close grown crops, horticultural crops, unplanted crop land, and other crop land
TOTPAST	total pasture land and range land, including estimates of pasture, range, and rotation hay and pasture
HUMAN	total land associated with human development, including estimates of urban land, roads, railroads, stripmines, and farm structures
NP	total estimates of natural pine
	estimates of natural pine by age class
NPA1	age class 1: 0–20 years
NPA2	age class 2: 21–50 years
NPA3	age class 3: 50+ years
PP	total estimates of planted pine
	estimates of planted pine by age class
PPA1	age class 1: 0–10 years
PPA2	age class 2: 11–30 years
PPA3	age class 3: 30+ years
OP	total estimates of oak-pine
	estimates of oak-pine by age class
OPA1	age class 1: 0–20 years
OPA2	age class 2: 21–50 years
OPA3	age class 3: 50+ years
UH	total estimates of upland hardwood
	estimates of upland hardwood by age class
UHA1	age class 1: 0–20 years
UHA2	age class 2: 21–50 years
UHA3	age class 3: 50+ years
LH	total estimates of lowland hardwood
	estimates of lowland hardwood by age class
LHA1	age class 1: 0–20 years
LHA2	age class 2: 21–50 years
LHA3	age class 3: 50+ years
AGE1	estimates for age class 1 across all forest types except planted pine
AGE2	estimates for age class 2 across all forest types except planted pine
AGE3	estimates for age class 3 across all forest types except planted pine
HWAGE1	estimates for age class 1 across hardwood types (oak-pine, upland hardwood, lowland hardwood)
HWAGE2	estimates for age class 2 across hardwood types (oak-pine, upland hardwood, lowland hardwood)
HWAGE3	estimates for age class 3 across hardwood types (oak-pine, upland hardwood, lowland hardwood)

were necessary to match these data to our model objectives. Commonly, state databases stratify the region into coldwater and warmwater fisheries, thereby eliminating a major source of regional variability and orienting the analysis to specific fish resources. For this pilot study, state surveys of trout streams in North Carolina (Bonner 1983) and Virginia (Neal 1980)[12] were selected because the state agencies had recently collected data with similar methods, and because these two states comprise the greatest extent of trout fisheries in the Southeast (fig. 1). All three species of trout—brook, brown, and rainbow trout—are present in these waters; however, in the model no distinction is made between species. By using total trout abundance, interspecific competition becomes less important as a factor structuring population estimates.

In these two surveys, state-designated trout streams were typically sampled once by single-pass electrofishing a 200–500 ft length of stream (Neal 1980, Bonner 1983),

[12]*Computer tape of the Virginia Stream Survey Retrieval System was obtained from the Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA.*

although in Virginia longer samples were taken where efficiency was low. A given stream was sampled in several reaches, and in North Carolina, a given reach was sampled on several different dates. No attempt was made to consolidate replicate samples. A total of 1311 stream samples from the mountain areas of North Carolina (537 streams sampled 1978–81) and Virginia (744 streams sampled 1975–79) comprise the coldwater fisheries database.

Both state surveys recorded numbers of each trout species in samples; however, some assumptions were necessary to convert the original numbers in samples into standardized area-based estimates (trout per acre of stream). For Virginia, we assumed the electrofishing probe rig sampled a maximum of 10 ft of stream width.[13] In North Carolina, a probe was used for smaller streams and 15- and 30-ft electric seines were used in larger streams (Bonner 1983). Although the different rigs probably had different success rates, we assumed the same success rate and made the following additional assumptions for North Carolina streams: in streams up to 15 ft and 20–30 ft in width, the entire stream width was sampled; 15 ft of width was sampled in streams 15–20 ft wide; and 30 ft of width was sampled in streams over 30 ft wide.[14]

The streams sampled for trout were located within the USGS gauged watersheds. Only 620 of the 1311 streams sampled had both trout present and were located within the gauged watersheds. Thus, the 60 watershed sample units used to build the model represent a sample of the coldwater area outlined in figure 1, limited by the overlap of trout-containing stream samples with USGS gauged watersheds.

Within watersheds, many stream samples contained no trout. Absence of trout in a sample is an ambiguous condition (we cannot determine whether there were no trout or whether trout were present but not captured), and incorporation of zero density in the data sets for individual watersheds creates a statistically intractable distribution. Therefore, all stream samples with a trout density of zero were eliminated, and the trout model predicts trout density (number per unit area) in those streams that do have trout. After the streams with no trout were eliminated from the database, the abundance estimates were found to be log-normally distributed within watersheds, and the density estimate for watersheds was the geometric mean of stream trout densities. To minimize errors that might result from assumptions made to calculate density, numerical estimates were converted into three abundance density classes. Twenty watersheds in the low density class had at least 1 individual up to 100 trout per acre of stream; 19 moderate density watersheds had 100–160 trout/acre; and 21 high density watersheds had more than 160 trout/acre. In the frequency distribution of abundances (i.e., geometric mean of abundance for each watershed), the high class forms a distinct peak. No such distinction clearly separates the low and medium abundance classes, and the boundary between these classes was selected to block for a confounding factor, physiographic strata. The watersheds in the fish model fall within both the Appalachian (43 watersheds) and Piedmont physiographic strata (17 watersheds). Preliminary analysis determined that land use and forest cover were significantly different between these two strata ($p < 0.05$). With the boundaries between abundance classes set as stated above, the numbers of watersheds in each stratum were distributed relatively equitably across abundance classes (Appalachian, 15, 13, 15; Piedmont, 5, 6, 6; total, 20, 19, 21; low, moderate, high, respectively).

In this analysis, we assume that the trout samples were synoptic; in the context of 50-year projections, the 7-year span of sampling is effectively synoptic. We further assume that the predictor variables, runoff and land use and land cover, are temporally associated with the trout estimates to describe the current relationships. The USGS flow data for 1973–1983 accomplish the temporal linkage between trout estimates made in 1978–1981 and the NRI survey in 1982 and FIA surveys in 1984 for North Carolina and 1977 for Virginia. Thus, trout, runoff, and land use and land cover are both spatially and temporally linked by the USGS watersheds to provide a basis for a statistical landscape model.

Model Development

Discriminant function analysis was used to develop a classification from the land and water data, capable of predicting trout density group membership from land use and water quantity projections. Linear discriminant function analysis is sensitive to two assumptions about the data, multivariate normality of independent variables within classification groups and homogeneity of covariance matrices among classification groups (Morrison 1967). Ecological data tend to violate these two assumptions, especially the latter, and particularly compromise results when used for descriptive purposes (Williams 1983). We chose to use the Statistical Analysis System (SAS Institute Inc. 1982a, 1982b) package because the UNIVARIATE procedure tests for univariate normality (Shapiro-Wilk statistic), and the DISCRIM procedure allows the user to test for homogeneity of covariance matrices and produces a quadratic discriminant function if the homogeneity test fails.

To meet the normality assumption, a natural logarithmic transformation of runoff and arcsine-square root transformations of land use proportions were necessary. Several land use variables were eliminated because the normality assumption could not be met after transformation. In this analysis, because sample sizes are small, a subset of the remaining independent variables must be selected. The variables were selected to be relatively uncorrelated and to produce the best discrimination among classes. Instead of using a statistical (e.g., stepwise) procedure to select variables, which introduces attendant problems (Habbema and Hermans 1977, Johnson 1981),

[13] *Based on personal conversation with Larry O. Mohn, Virginia Commission of Game and Inland Fisheries, Staunton, Virginia, 1986.*

[14] *Based on personal conversation with Wayne Jones, North Carolina Wildlife Resources Commission, Division of Inland Fisheries, Waynesville, North Carolina, 1986.*

the following procedure was followed: The transformed independent variables from table 2 that passed the normality test were grouped to minimize correlations among variables. Candidate models were constructed by a sequential elimination of variables from each group of variables. The test for homogeneity of covariances among trout density classes nearly always failed, and the SAS discriminant analysis proceeded with the nonlinear quadratic form. The model with the minimum number of independent variables and with the maximum reclassification success (percentage of watersheds that are correctly classified in a reclassification by the model) was selected (Habbema and Hermans 1977).

The selected model (table 3) classifies trout density class as a quadratic discriminant function of seven independent variables, RUNOFF, TOTCRP, HUMAN, NPA1, NPA2, HWAGE2, and HWAGE3, with a reclassification success of 78.3%. In this model, high trout density is associated with the highest coverage of old-age hardwoods (HWAGE3) and the lowest proportion of land devoted to human uses (HUMAN) and cropland (TOTCRP) (table 3). Lowest trout density was associated with highest proportion of human land uses. Implicit in these relationships are factors such as water temperature, sediment load, instream cover, food resources, and shading that are favorable for trout in areas with old hardwoods (Sedell and Swanson 1984) and are unfavorable for trout in areas with large amounts of human land use.

MODEL APPLICATION

For regional projections of the trout resource, the discriminant function analysis results were extended into areas of northern Georgia and extreme northwestern South Carolina where trout are known to occur but where abundance data were lacking. Fourteen watersheds were added to the original 60 from Virginia and North Carolina (fig. 1).

Regional projections of land use and forest types for 1985 through 2030 from the land area model (Alig 1984) and timber growth and yield model (Tedder 1983, Tedder et al. 1987) were applied to the discriminant function analysis model to produce an analysis of a likely future for the trout resource (the baseline scenario) and several alternative scenarios (see Appendix). Projected land use and land cover acreages for the years 1985, 1990, 2000, 2010, 2020, and 2030 were converted to proportions of each watershed by the raking method described above. In effect, changes projected for each time step were allocated among states, counties, and watersheds in proportion to the area present at the beginning of each time step. Before raking, site class and stocking class cells projected by TRIM were collapsed into cover type and age class cells by ownership. Although not explicit in the trout model, ownership (national forest, other public, forest industry, and other private) was tracked because current and projected timber management behavior varies among owners, and distribution of ownerships also varies across the Southeast. For example, most of the National Forests of the region are in the higher elevations and retain older age classes of forest. The forest industry and other private owners, which predominate in other areas of the Southeast, are assumed by TRIM to cut younger age classes of both pine and hardwood forest types than do federal owners.[10]

Land use and forest cover type projections were made for the entire Southern United States. In the following discussions and figures, data are given only for the watersheds that comprise the coldwater area of the Southeast; therefore, the land base description will differ from that reported elsewhere (Flather et al. in press, Joyce in press).[10]

For a watershed, yield (ft/year) was predicted as a function of the proportion of watershed land area in different

Table 3.—Results of quadratic discriminant function analysis; (a) mean (standard error) transformed value of each predictor variable for each trout abundance class; and (b) final classification summary table for the calibration data, number of observations from original class (rows) classified into column class (% of original class).

A.

Predictor variable	Trout abundance class: Low	Moderate	High
RUNOFF	0.572 (0.066)	0.622 (0.076)	0.620 (0.095)
TOTCRP	0.202 (0.019)	0.219 (0.026)	0.186 (0.019)
HUMAN	0.280 (0.014)	0.251 (0.014)	0.244 (0.012)
NPA1	0.123 (0.021)	0.109 (0.019)	0.115 (0.014)
NPA2	0.196 (0.025)	0.179 (0.023)	0.161 (0.017)
HWAGE2	0.473 (0.019)	0.483 (0.020)	0.447 (0.023)
HWAGE3	0.552 (0.025)	0.539 (0.034)	0.618 (0.035)

B.

From class	To class: Low	Moderate	High
Low	17 (85)	2 (10)	1 (5)
Moderate	4 (21)	12 (63)	3 (16)
High	1 (5)	2 (10)	18 (86)
Total	22	16	22
Percent of total	37	27	37

land use and forest cover categories and runoff estimates based on literature and expert opinion.[15]

Trout density for the Southeast region was estimated as follows. Classification produces a posterior probability of membership in each of the three classes for each watershed; averaged over all watersheds, those probabilities become regional probabilities for each class. Regional probabilities were not weighted by watershed size because the trout densities of large watersheds would be inappropriately emphasized over those of small watersheds. Trout streams are distributed relatively uniformly within small watersheds. However, as watershed size increases, higher order streams that do not support trout are included in the watershed, and trout streams are found in only a portion of the watershed. The very largest watersheds in the model contain a large number of trout streams, but also include acreage that is not in the coldwater area. Expected densities of 50, 130, and 363 trout/acre (the midpoints of each class) were assigned to the low, moderate, and high density classes, respectively. Average regional probabilities were multiplied by these expected densities and summed to obtain a single, regional estimate of trout density (number per acre of trout stream).

Ecological Assumptions

Several assumptions were made in model development and application. These assumptions should be considered when interpreting the model results and applications.

Few sampling programs have been designed with regional analysis as an objective. The North Carolina and Virginia data sets provided a rare opportunity to analyze a relatively large geographic area. Nevertheless, several aspects of the state fish sampling programs require assumptions be made for the analysis: The estimates of trout density are based on trout captured by single-pass electrofishing. Furthermore, similar capture efficiencies were assumed, regardless of stream size and some differences in sampling rigs. Thus, the projected trout densities are those that would be perceived with future sampling programs designed around similar methods. The size distribution of trout in the stream samples was unknown and assumed to be similar across trout density classes. Abundance estimates represent summer populations because sampling surveys were generally made between May and September. Trout density estimates apply to accessible trout streams in the coldwater area. A different data base and analysis would be required to include all streams because the states sampled only streams likely to have trout that were accessible, both legally and physically (Bonner 1983).

Stocking is practiced by both states, but in both cases, the trout sampled represent populations capable of surviving throughout the year. Trout and stream habitat management are not explicit in the analysis. To the extent that these management practices determine trout density at the time of sampling, trout management actions are implicit in the analysis. In the projections, stocking and other trout management practices (e.g., riparian zone management, stream structures) are assumed to continue in the future at the level practiced in the 1970's and early 1980's.

All factors that affect trout abundance and are external to the relationship between trout and the watershed land base are also assumed to be constant both across watersheds and through the projection period. For example, competition between trout and other fish species is assumed constant. Some factors that affect trout (e.g., point sources of pollution and water treatment) are inherent in human land use, and the implied relationship between trout habitat quality and human land use is assumed constant. The rate of trout harvest is also linked to human land use, and the linkage is assumed constant throughout the region and through time.

In constructing the land base, counties were assumed to be homogeneous; that is, the proportion of each land use and forest type applies to all partitions of the county. When parts of counties were reallocated to watersheds, homogeneity within the watershed was also assumed, so that the land uses and forest types could be related to the trout density class for that watershed.

Annual runoff was calculated from flow records at the base of the watershed for the 1973–1983 period. In the analysis, runoff measured at the base of the watershed is assumed to apply to the watershed as a whole. For example, if the runoff for a watershed is 2 ft/year, the amount of water spread 2 ft deep over the entire watershed runs off in each year. From the perspective of trout, the assumption is that increases or decreases in runoff will be reflected in increases or decreases of flow in trout streams. In the projections, future precipitation will average the same as it was in the 1973–1983 period, and changes in runoff are assumed to be due solely to land changes. That is, no additional water management programs, such as damming or diversion, will be implemented. Also, the projections assume that increased runoff will be spread uniformly throughout the watershed.

The watersheds used to calibrate the model are a sample of the land base, dependent largely on the location of USGS gauges monitored more or less continuously during 1973–1983. The sample is also dependent on location of at least one trout stream, as defined by the fish database, within each gauged watersheds. The sample is 40–50% of the coldwater area and is assumed to be random and representative of the Southeast coldwater fishery.

In applying the projections, regional and state level changes are allocated to counties based on the relative size of each county and the relative importance of each land use or forest type in the county. The resulting county land base is proportionally allocated to watersheds. Thus, regional changes in a given land use or forest type are assumed to apply to all counties and watersheds in proportion to the amount of land in that type. Furthermore, the trout density relationship to land use, forest

[15]*The South's Fourth Forest: Regional Water Response to Timber Management, unpublished report by Stan Ursic, USDA Forest Service, Forest Hydrology Laboratory, Southern Forest Experiment Station, Oxford, MS, 1986. 21 p. + appendix.*

type, and runoff established for Virginia and North Carolina watersheds is assumed to apply to northern Georgia and northwestern South Carolina watersheds.

Baseline Scenario

The baseline projection describes the timber situation, provided that assumptions about supply and demand are realized.[10] Present expectations about human population growth, economic activity, income, and product prices determine expected demand, while changes in the area of timberland, timber management intensity, timber growth, and stumpage prices determine future supply under the baseline scenario. A number of timber-related assumptions were incorporated in the projection, including a level of timberland management that was more intense than current management.

Under the baseline scenario, increasing human population results in an increase of land devoted to direct human land use (from 7.5% in 1985 to 9.8% in 2030). In the coldwater area, cropland and pastureland uses remain nearly constant over the period. Total forestland declines from 64.6% to 62.2% between 1985 and 2030. Natural forest types, especially natural pine, are converted to planted pine in the baseline run; however, because planted pine is rare in the coldwater area (1.5% of the land base in 1985), total planted pine increases to only 3.2% in 2030. The oldest age classes of natural pine, oak-pine, and upland hardwood forest decrease as the forests undergo a harvest, but increases in the youngest age class indicate regeneration of the same forest type.

Among the land use and timber variables in the trout projection model (fig. 6), the proportion of old-age hardwoods (HWAGE3) in the land base declines most dramatically after 2000. Middle-age hardwoods (HWAGE2) decline through 2010, but this decline largely represents growth and aging of stands to the old age class. Total hardwoods decline only slightly (from 54.2% to 53.2% in 2030) over the projection period; however, the age structure changes dramatically as older hardwood stands are cut and regenerate over time. In the natural pine age classes, the dynamics between young (NPA1) and middle (NPA2) age classes also represent a cycle of cutting and regrowth (fig. 6). The importance of natural pine in the coldwater area land base is minor, and these small changes, relative to those in hardwood age classes, are not likely to exert a large influence on trout density. Cropland remains nearly constant throughout the projection period, and human land uses increase predictably (fig. 6). Over the projection period, annual runoff increases by about 1 inch per year (fig. 6).

These projections of land use and forest type age classes and of runoff result in a decrease of 47 trout/acre from the 1985 density of 173 trout/acre (fig. 7, table 4), corresponding to a 27% decline between 1985 and 2030. The decline of trout abundance is largely in response to the decline of old-age hardwoods (over 50 years of age) and increased human land use over the projection period. As older hardwood acreages decline over time, shading declines and water temperature increases. At the same time human land use is increasing at the expense of higher quality trout habitat. Trout density declines under these land use and forest cover changes and the attendant modification of trout habitat.

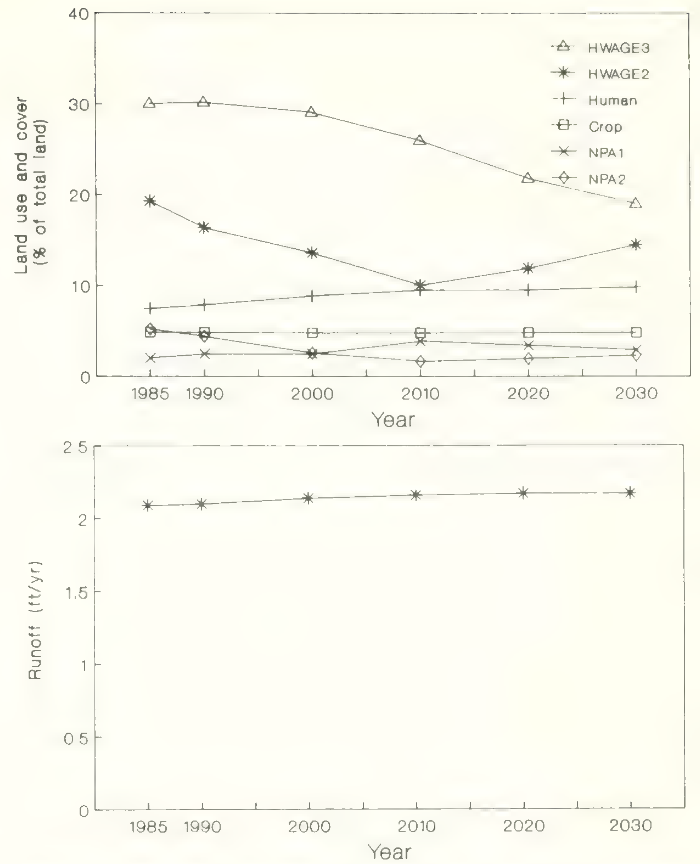

Figure 6.—Baseline projections for trout density predictor variables: (a) percent of land uses and cover types in coldwater area over the baseline projection; and (b) feet of runoff per year in the coldwater area over the baseline projection.

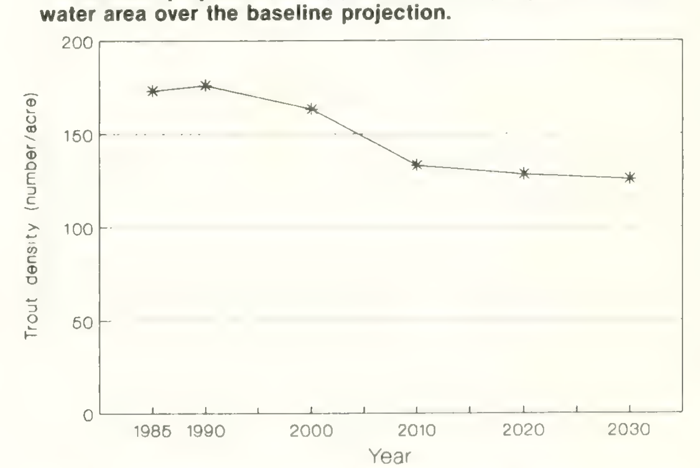

Figure 7.—Baseline projection of trout density (number per acre of trout stream in watersheds) for the coldwater area. The overall decline is 27%.

Alternative Scenarios

In the Southern Timber Supply Study, several alternative futures were considered (see the Appendix for a description of the assumptions behind each scenario).

Table 4.—Trout density (number/acre of trout stream) for Southeastern coldwater watersheds under baseline and alternative scenarios.

	Baseline	Increased stumpage cost 7	Reduced timberland area 8	Reduced timber growth 9	Reduced NF harvest 10	Economic opportu-nities 13
1985	173	173	173	173	173	173
1990	176	176	178	177	178	174
2000	163	162	173	168	168	156
2010	133	130	156	135	129	127
2020	128	124	155	128	119	126
2030	126	122	155	123	119	124

We analyzed the five scenarios that produced changes in the commonly defined land base for impacts on trout density with the trout model:

7. Increased stumpage costs over those in the baseline run;
8. Reduced timberland area by conversion of marginal timberland to cropland;
9. Reduced timber growth for natural pine, planted pine, and oak-pine;
10. Reduced National Forest harvest;
13. Economic opportunities on private timberland.

These scenarios were developed to test alternative timber management strategies, and variations in land use and timber cover among the several scenarios were small. The scenarios were not designed to represent land use and forest cover changes that could be significant for the trout resource. Consequently, the variation in trout density was smaller among scenarios than the change observed over the projection period in the baseline and all scenarios. Trout densities projected for 1985 under all scenarios were nearly identical (table 4); to make comparisons among scenarios more effective (fig. 8), all projected densities were indexed to the corresponding 1985 density (from table 4). Likewise, in figures 9–14, land uses and cover are indexed to the 1985 value. Runoff does not vary among scenarios. In the following discussions of the individual scenarios, only deviations of each scenario from the baseline will be discussed.

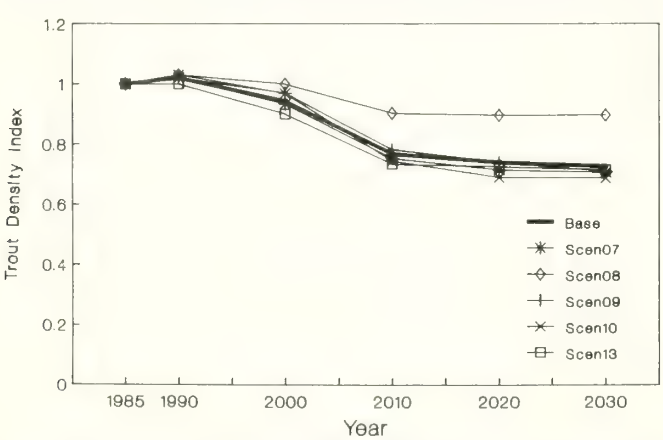

Figure 8.—Comparison of trout density index among baseline and alternate scenarios for Southeastern coldwater watersheds. Index is the ratio of trout density in a given year for a given scenario to the 1985 density under the same scenario. Scenarios are numbered: Increased Stumpage Costs (Scenario 7), Reduced Timberland Area (Scenario 8), Reduced Timber Growth (Scenario 9), Reduced National Forest Harvest (Scenario 10), and Economic Opportunities on Private Timberland (Scenario 13).

Increased Stumpage Costs

Although softwood inventories build under this scenario of increased stumpage costs, the proportion of land in young and middle-age natural pine and middle- and old-age hardwoods is nearly the same as the baseline (figs. 11–14). After 2010, old-age hardwood acres drop below the baseline acres (fig. 14) and trout density also drops slightly (fig. 8). Trout density response under this scenario is nearly the same as the response under the baseline projection because management under this scenario does not shift acres of land use or forest cover types.

Reduced Timberland Area

Conversion of timberland to cropland is spread over all forest types and ages, so that the proportion of land in forest type age classes differs from the baseline by only small amounts, especially when compared to the changes over time. In fact, for natural pine and hardwood age classes, this scenario diverges less from the baseline than do other scenarios (figs. 11–14). Human land use acres are very slightly higher at 2030 (fig. 10). The only large difference in the land base is increased cropland acreage (fig. 9). Although the increase in cropland in figure 9 appears dramatic, this increase represents a small change in cropland from 4.9% of total land in 1985 to 6.6% in 2030. The changes in acreage of both forest type age classes and land uses combine to produce a smaller decline in trout density compared to the baseline decline (fig. 8). Under this scenario, increased cropland acreage is not a factor that increases trout density, but a factor that moderates the decline of trout in the context of increasing human land use and decreasing old-age hardwoods. Trout density declines because old-age hardwood acres decrease and human land use acres increase as much as in the baseline projection, and trout habitat is degraded with those changes. The reason for a more moderate decline under this scenario of increased crop-

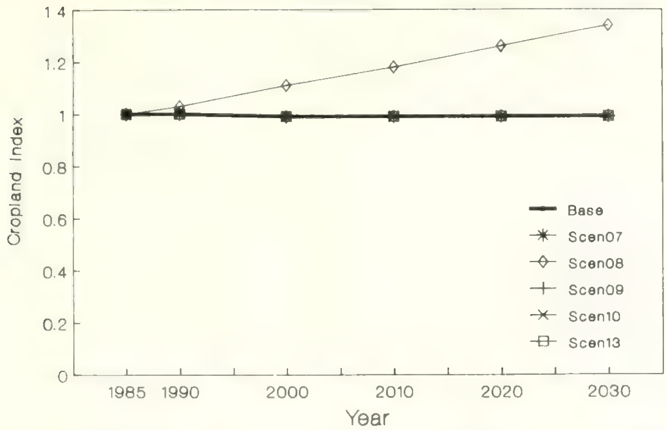

Figure 9.—Comparison of total cropland among baseline and alternate scenarios for Southeastern coldwater watersheds. Index is calculated and scenarios are numbered as described for figure 8.

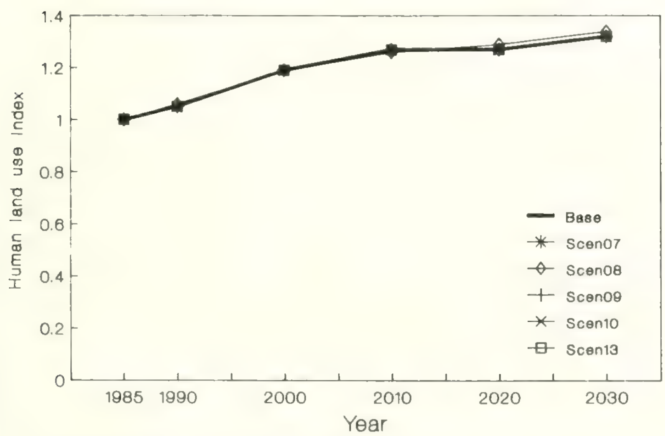

Figure 10.—Comparison of human land use among baseline and alternate scenarios for Southeastern coldwater watersheds. Index is calculated and scenarios are numbered as described for figure 8.

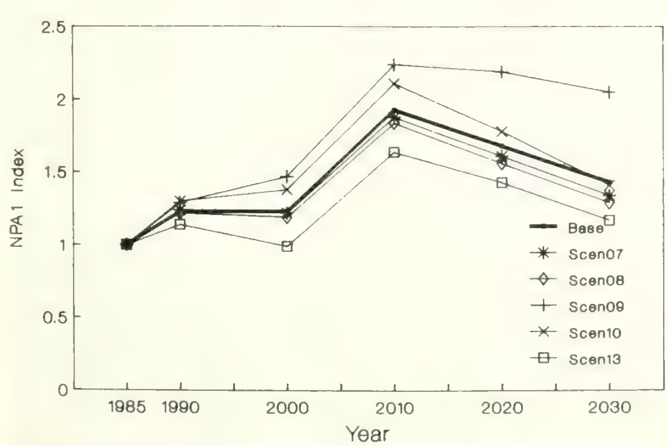

Figure 11.—Comparison of young natural pine (0–20 years) among baseline and alternate scenarios for Southeastern coldwater watersheds. Index is calculated and scenarios are numbered as described for figure 8.

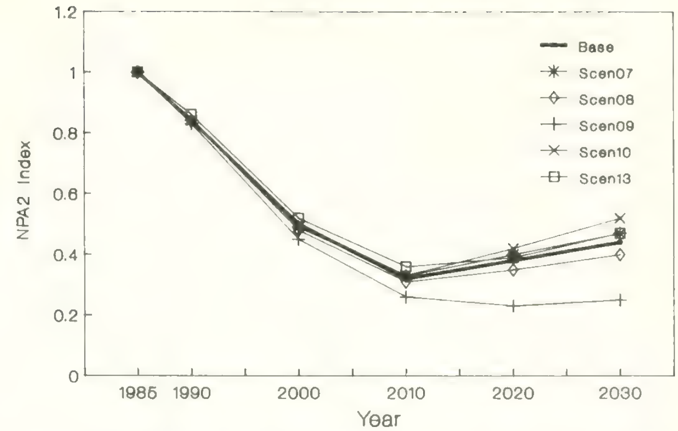

Figure 12.—Comparison of middle-age natural pine (21–50 years) among baseline and alternate scenarios for Southeastern coldwater watersheds. Index is calculated and scenarios are numbered as described for figure 8.

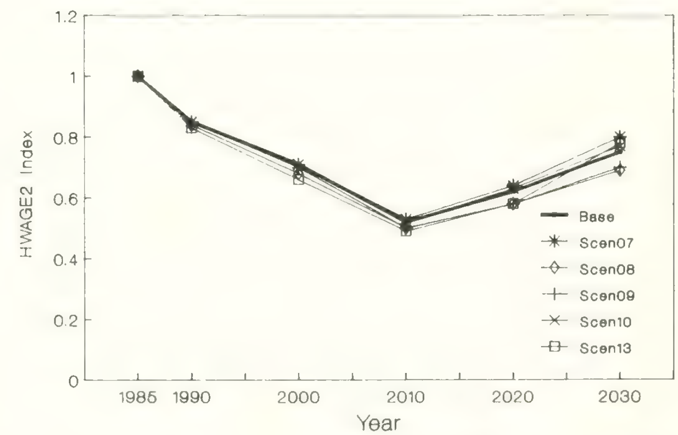

Figure 13.—Comparison of middle-age hardwoods (21–50 years) among baseline and alternate scenarios for Southeastern coldwater watersheds. Index is calculated and scenarios are numbered as described for figure 8.

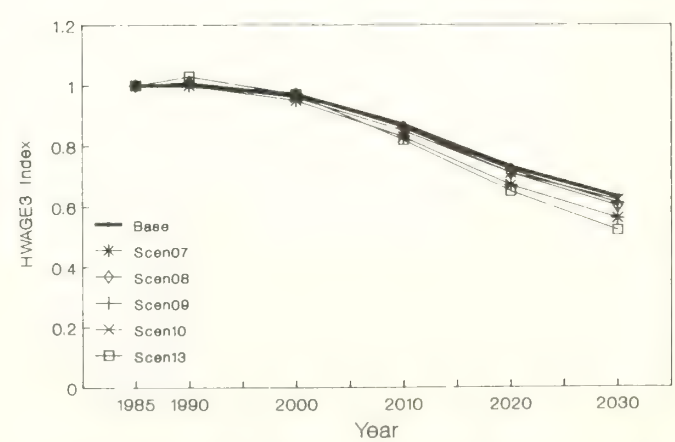

Figure 14.—Comparison of old-age hardwoods (over 50 years) among baseline and alternate scenarios for Southeastern coldwater watersheds. Index is calculated and scenarios are numbered as described for figure 8.

land can only be surmised. The watersheds that deviate from baseline behavior are concentrated in northern Virginia, mainly in the Shenandoah Valley, where cropland acreages and the associated increases may occur below trout streams in the watersheds.

Reduced Timber Growth

Under the decreased timber growth scenario, acres of natural pine in the youngest age class are higher (fig. 11) and acres of natural pines in the 20–50 year age class are lower than in the baseline (fig. 12), especially after 2000. These two forest age class effects tend to cancel in the trout analysis, and the net result is to project trout densities near the baseline densities. The hardwood age class acreages are slightly below baseline (figs. 13–14). Compared to the baseline, the decline of trout density is slightly slower through 2010 and faster after 2010 (fig. 8, table 4). Trout density projected under this scenario is not different from trout density under the baseline projection because the old-age hardwood acreage decrease and human land use acreage increase are not moderated under this scenario, and trout habitat is degraded as in the baseline projection.

Reduced National Forest Harvest

Under decreased National Forest (NF) harvest, the changes are largely confined to acres of natural pine age classes (figs. 11–12). Even though a large part of the coldwater area is in NF ownership, hardwood types dominate, and natural pine acres are a relatively minor component of forestland. Thus, the impact of reduced NF harvest on trout is minimal. The proportion of land in the hardwood age classes (figs. 13–14) is again very similar to the baseline case. There are some increases in the acreage of natural pine age classes (figs. 11–12), but these differences are both small and transient (as those stands age). The trout analysis is relatively insensitive to natural pine age class acreage shifts; thus, trout density response is similar to the baseline (fig. 8). In 2020 and 2030, trout density drops slightly below baseline, probably due to the increase of middle-age natural pine (fig. 12). The decline of old-age hardwood acreage is as large as the decline projected under the baseline, and acres of human land uses are not modified under this scenario. Degradation of trout habitat associated with these two changes is not modified by the scenario, and trout density declines as in the baseline projection.

Economic Opportunities on Private Timberland

The limited set of economic opportunities, over and above those in the baseline, result in small differences in land use acreages (figs. 9–10), and some differences in forest type age classes. The largest difference is decreased acres of young natural pine (fig. 11). Middle-age natural pine acres are only slightly above the baseline throughout the projection period (fig. 12). Middle-age hardwood acres are below the baseline from 1990 through 2020 (fig. 13). Old-age hardwood acres decrease more than the baseline (fig. 14); by 2030, the difference appears large, but that difference is small compared to the magnitude of change between 1985 and 2030. The result of the changes to the land base under this scenario is a more rapid decline of trout density between 1990 and 2010 and leveling off after 2010 slightly below the baseline projection (fig. 8). Just as in the baseline projection, trout density declines because old-age hardwood acres decline and human land use acres increase. The assumption of increased economic opportunities under this scenario results in a slightly more rapid degradation of trout habitat than under the baseline projection, and trout density declines more rapidly. After 2010, acres of old-age hardwoods have decreased and acres of human land use have increased to a point where trout density is no longer sensitive to differences in the land base generated by the increased economic opportunities.

MANAGEMENT AND RESEARCH IMPLICATIONS

Management Implications

The analysis of present trout density and the land base established the relationship between trout and their watershed habitat on a regional scale. The trout model operated at the level of watersheds and incorporated habitat modifications beyond the immediate stream environment (i.e., forest cover changes in the context of major land use changes). Regional model results indicated that watershed land use management is an important consideration for planning and managing the Southeastern trout fishery.

Alternative scenarios were designed to evaluate impacts of economically important alternatives on supply and inventory volume of timber, especially of softwoods; therefore, land base differences among scenarios were not dramatic for coldwater watersheds. With one exception, the alternative management scenarios tested did not mitigate the decline of trout density observed under the baseline scenario. The model was more sensitive to major land use changes and to harvest of mature hardwood acres than to the details of timber management within the watershed. Management decisions that change harvest of old-age hardwood acres or conversion of forest to human and cropland uses are more likely to be significant to regional trout density than the management alternatives examined here.

Present stream management, including that associated with timber harvest (e.g., leaving riparian buffer strips), was implicit in the model and did not offset effects of land use changes and removal of old-age hardwoods. More intense stream level management, including additional stream habitat improvement, increased trout populations through stocking programs, or trout harvest limitations, may be required to moderate the effect of projected watershed land use and timber harvest. However, this analysis does not identify which, if any, of these management opportunities may successfully mitigate the decline.

The analysis points to the need for management to mitigate the projected decline, particularly in the face of continued increases in numbers of users. If the number of users continues to increase as in the past, will the additional Dingell-Johnson funds generated by expenditures be sufficient to cover increasingly intensive trout management? On the other hand, decreased quality of fishing experience may result in decreased numbers of users, expenditures, and available funds.

The regional trout model presented here provides limited ability to address site-specific management questions. We can say that region-wide harvest of old-age hardwoods results in regional declines of trout density, but we cannot predict what will happen to trout in a particular watershed with this model. Watershed level research would address questions of importance to management of individual watersheds. Although stream habitat is implicit in the relationship between trout density and old-age hardwoods that provide favorable stream conditions for trout, effects of enhanced stream management, such as riparian zone management, cannot be evaluated by this analysis. Finally, the model cannot evaluate the relative effectiveness of watershed management over stream management. Nevertheless, this regional analysis does provide a unique perspective for trout management. The analysis demonstrated that regional landscape patterns, particularly the acreages of old-age hardwoods and human land use, are important to the abundance of trout in the region. Although local stream management is not capable of addressing regional patterns, managing hardwood forests on a regional scale and planning the growth of human related land use may prove successful for maintaining the trout resource.

Research Opportunities

The objective of the fish analysis was to provide results from which planners and policy makers could assess the possible impacts resulting from changes in land use and timber management activities. In the context of the multiresource framework, this analysis represents an initial effort to quantitatively incorporate other resource considerations into the traditional single resource analysis for a large region. Now that the framework has been specified and applied, we can recommend future research that will permit explicit incorporation of the assumptions made in this analysis. Future research can include more detailed representations of the complex relationships that exist between fish and the land and water resources that affect fish.

Many of the ecological assumptions described above provide opportunities for future research. Trout stocking is significant in the region, and future regional analysis should explicitly incorporate stocking; comparisons of wild trout fisheries with stocked fisheries would be possible with this enhancement to regional analysis. Significant external factors and those implicit in land use and forest cover acreages should be incorporated explicitly in future regional models, as should details of forest and stream management, including riparian buffer strips. More detailed descriptions of the land base within watersheds and of the projected changes would improve the regional model by eliminating the need for assumptions about a homogeneous land base within watersheds and allocation of projected changes. Finally, redefinition of watersheds to create a random and representative sample set of watersheds would eliminate assumptions about runoff and watershed selection.

The regional scale of the trout model presents both opportunities and challenges for future research. The relationships between trout and the watershed habitat established statistically by the model should be verified experimentally for the region and for watersheds. The relative importance of watershed habitat compared to stream habitat should also be addressed with future research.

All models require verification and validation, and this one has not been completely tested. Validation, where model output is compared to independent data, is particularly difficult when predictions are made into the future. Backcasting to earlier time periods is possible, but requires that all three kinds of data—trout abundance, water yield, and land use and forest cover—be available for the same time period. The regional scale of this model presents special problems for validation. An adequate validation requires that comparable data be available for a large portion of the region, not just for a single watershed. Regional trout abundance data are not available for an earlier time. Given these constraints, we are presently limited to internal validation with the jackknife method (Lachenbruch 1975), a verification of the model using the single combined database used to build the model presented here. This research is in progress and will be reported later.

The regional analysis should also be extended to other fish resources, such as warmwater fish, which are a more diverse group and are less specific in their habitat requirements. Warmwater species are expected to present a greater challenge to the researcher. Availability of fish data will limit the opportunities to produce additional regional fish production models.

We can suggest changes for timber growth and yield models that would promote multiple resource analyses. Models that incorporate information about riparian zones associated with forest types would make timber resource projections more responsive to fish habitat management practices. Assumptions of timber growth and yield models should incorporate timber management restrictions imposed by the need to manage fish habitat. Economic supply and demand assumptions should consider the value of other resources like trout. In the future, as income from leasing of fishing rights increases, timber model assumptions about forest owner behavior should be modified.

CONCLUSIONS

Since stocking programs were initiated that introduced nonnative rainbow and brown trout to the Southeast in

the early 20th century, the range of native brook trout has shrunk. Presently, limited wild brook trout populations persist, primarily in headwater streams. Some wild rainbow trout populations are also found. Populations of all three species are maintained by active stocking programs of both the state and federal hatcheries.

Quadratic discriminant function analysis established relationships between present trout density in trout streams and the watershed land base and runoff. Projected trout density is a function of both land in forest type age classes and land devoted to the major nonforest cropland and human land use. Thus, changes in acres of forestland are considered in combination with changes in acres of nonforest land uses to predict future trout densities. The trout analysis tends to be more sensitive to changes that involve shifts of forestland acres, particularly old hardwoods, into other land uses, especially to human land use.

Although the decline of hardwood acres over the baseline projection period is small, the age structure will change dramatically, resulting in a large decline in old-age hardwood acres in coldwater areas where hardwoods dominate the landscape. Regenerated hardwood stands begin to show up in the middle-age class by 2020; however, none reach old-age status by the end of the projection period in 2030. Trout density declines over time because high trout densities are associated with high acreages of old-age hardwoods. Human land use increases over the projection period contribute to the degradation of trout habitat and trout density.

In general, trout density responses are similar under all scenarios. Differences among the scenarios in acres of cropland, human land use, natural pine and hardwood age classes are small when compared with the change in acres over time. Runoff varies imperceptibly among the scenarios. Most of the scenarios target management related to pine type areas, specifically the dynamics between natural and planted pine types. Those differences represent relatively small acreage shifts for the coldwater areas of Virginia, North Carolina, South Carolina, and Georgia because natural pine is not common and planted pine is very rare. In the analysis, trout density appears to be relatively insensitive to changes in natural pine acreages. Therefore, interpretation of the results must recognize that the scenarios do not necessarily produce changes in acreage of the hardwood forest cover types that are important for high trout density and that dominate the landscape in the coldwater area. Only the Reduced Timberland Area scenario projects a change in land use acres that differs from the baseline, and only in that scenario does trout density respond differently from the baseline.

In the context of continuing increases in fishing, the projected decline of trout production suggests that additional management for trout may be necessary. Management may be focused at regional, watershed, or stream levels. Specific management actions could address either enhanced production through timber management, habitat improvement, or increased stocking, or may require restrictions on trout harvest.

The regional analysis method presented here, imbedded in a multiple resource modeling framework, successfully captured relationships between trout and their watershed habitat. Although numerous assumptions were required, the feasibility of a regional approach to trout habitat relationships was demonstrated. The regional watershed approach allowed us to present future trout production estimates and to evaluate several timber management alternatives. Future timber growth and multiple resource models can explicitly incorporate fish habitat management to achieve more complete analysis of multiple resource questions.

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APPENDIX: DESCRIPTION OF ALTERNATIVE SCENARIOS

1. **Wharton growth assumptions with cycles**.—The future as described by the basic assumptions and other specified and implied assumptions,[10] modified by substituting the assumptions on population, gross national product, per-capita disposable income, housing and other demand determinants, including economic cycles, contained in "Long-term Alternative Scenarios and 20-year Extension," Wharton Econometric Forecasting Associates, Vol. 3., No. 1, February 1985, for those contained in this study through 2005. For years after 2005, the assumptions used in this report were adjusted to be consistent with the Wharton 20-year trends and levels.

2. **Improved processing efficiency**.—The future as described by the basic assumptions and other specified and implied assumptions,[10] modified by increasing lumber and plywood yields 15 percentage points above the 10% increase assumed in the base projections. The increase in yields will be staged in the progression 9%, 7%, 5%, 3% and 1% per decade.

3. **Fifteen percent softwood lumber tariffs**.—The future as described by the basic assumptions and other specified and implied assumptions,[10] modified by the imposition of a 15% ad valorem duty on softwood lumber imports effective in 1986.

4. **High exports of timber products**.—The future as described by the basic assumptions and other specified and implied assumptions,[10] modified by increasing the projected exports of lumber, plywood, and pulpwood (including pulpwood and the pulpwood equivalent of pulp, paper, and board) by 20% in 1990, 40% in 2000, 60% in 2010, 80% in 2020, and 100 percent in 2030.

5. **High imports of timber products**.—The future as described by the basic assumptions and other specified and implied assumptions,[10] modified by increasing the projected imports of plywood, pulpwood (including pulpwood and the pulpwood equivalent of pulp, paper, and board), and hardwood lumber and logs by 20% in 1990, 40% in 2000, 60% in 2010, 80% in 2020, and 100% in 2030.

6. **Reduced U.S./Canadian exchange rate**.—The future as described by the basic assumptions and other specified and implied assumptions,[10] modified by reducing the U.S. exchange rate with Canada—U.S. dollars per Canadian dollar—to 0.80 in 1990, 0.85 in 2000, and 0.90 in 2030. In the basic assumptions, the exchange rate was assumed to be 0.86 in 1990, 0.95 in 2000 and 0.98 in 2030.

7. **Increased stumpage costs**.—The future as described by the basic assumptions and other specified and implied assumptions,[10] modified by increasing stumpage prices above the base projections by 5% by 1990, 10% by 2000, 15% by 2010, and 20% by 2020.

8. **Reduced timberland area**.—The future as described by the basic assumptions and other specified and implied assumptions,[10] modified by reducing the projected area in timberland in the South by 2 million acres in 1990, 5 million acres in 2000, and 11 million acres in 2030.

9. **Reduced timber growth**.—The future as described by the basic assumptions and other specified and implied assumptions,[10] modified by reducing by 25% the net annual growth on pine plantations, natural pine, and mixed pine-hardwood stands shown in the empirical yield tables used in developing the base-level projections.

10. **Reduced National Forest harvest**.—The future as described by the basic and other specified and implied assumptions,[10] modified by reducing timber harvests on the National Forests to 8.1 billion board-feet in 1990 and maintaining this level through 2030.

11. **Natural regeneration on cropland and pastureland**.—The future as described by the basic assumptions and other specified and implied assumptions,[10] modified by assuming that all the cropland and pastureland in the South that would yield higher rates of return in pine plantations would naturally revert to timberland by 2000 (70% natural pine, 30% hardwoods in the Southeast; 40% natural pine, 60% hardwoods in the South Central).

12. **Economic opportunities on cropland and pastureland**.—The future as described by the basic assumptions and other specified and implied assumptions,[10] modified by assuming that all the economic opportunities (those that would yield 4% or more net of inflation or deflation) for establishing pine plantations on marginal cropland and pastureland would be utilized.

13. **Economic opportunities on private timberlands**.—The future as described by the basic assumptions and other specified and implied assumptions,[10] modified by assuming that all the economic opportunities for increasing timber supplies on timberland in private ownerships that yield 4 percent or more net of inflation or deflation would be utilized.

14. **Increased management intensity on forest industry timberlands in the Douglas-fir region**.—The future as described by the basic assumptions and other specified and implied assumptions,[10] modified by assuming that all the economic opportunities to increase timber supplies on forest industry timberlands in the Douglas-fir region would be utilized.

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky Mountains

Southwest

Great Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526